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TECHNICAL REPORT 4588

SPIN-73
AN UPDATED VERSION OF THE SPINNER COMPUTER PROGRAM

ROBERT H. WHYTE

NOVEMBER 1973

PICATINNY ARSENAL
DOVER, NEW JERSEY 07801

Technical Report 4588

SPIN-73
AN UPDATFD VERSION OF THE SPINNER COMPUTER PROGRAM

by

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FOREWORD

This report documents tasks accomplished by the Armament Systems Department, General Electric Company, Burlington, Vermont under United States Government Contract No. DAAA21-73-C-0033 during the period from 14 August 1972 to 14 July 1973.

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ABSTRACT

The SPINNER computer program has been updated to compute aerodynamic coefficients for a wide variety of spin stabilized projectile shapes. Improvements over the original program are substantial as ogive radius, meplat diameter and rotating band diameter are accounted for instead of assuming mean values. Test cases are shown comparing the 1969 SPINNER, the 1973 SPINNER and experimental data. Input instructions and sample program outputs are given along with the 1973 program listing.

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NOMENCLATURE

A	projectile cross-sectional area, ft^2
C_{l_p}	spin deceleration coefficient, $M_{l_p}/\bar{q}Ad(\frac{pd}{2V})$
C_m	pitching moment coefficient, $M_m/\bar{q}Ad$
C_{m_q}	damping moment coefficient, $M_{m_q}/\bar{q}Ad(qd/2V)$
C_{n_p}	magnus moment coefficient, $M_{n_p}/\bar{q}Ad(pd/2V)$
C_N	normal force coefficient, $F_N/\bar{q}A$
C_{Yp}	magnus force coefficient, $F_{Yp}/\bar{q}A(pd/2V)$
C_X	axial force coefficient, $F_X/\bar{q}A$
CG	center of gravity, calibers from nose
I_x	axial moment of inertia, slug-ft^2
I_y	transverse moment of inertia, slug-ft^2
F_N	normal force, lbs.
F_{Yp}	magnus force, lbs.
F_x	axial force, lbs.
M_{l_p}	spin damping moment
M_m	pitching moment about CG
M_{m_q}	damping moment about CG
M_{n_p}	magnus moment about CG
V	total velocity, ft/sec.
d	projectile diameter, ft.
g	gravity, 32.174 ft/sec^2
m	projectile mass, slugs
p	projectile spin rate, radians/second
q	projectile pitch rate, radians/second

NOMENCLATURE (Continued)

$\bar{q}$	dynamic pressure, $1/2\rho\ V^2$, lb/ft^2
$\bar{\alpha}$	total angle of attack, radians
ρ	air density, $slugs/ft^3$

Subscripts

α	Derivative with respect to $\sin \bar{\alpha}$
2	Derivative with respect to $\sin^2 \bar{\alpha}$
α_3	Derivative with respect to $\sin^3 \bar{\alpha}$
α_5	Derivative with respect to $\sin^5 \bar{\alpha}$

INTRODUCTION

The Armament Department of General Electric under contract to Picatinny Arsenal has developed an empirical computerized model for predicting the aerodynamic coefficients of spin stabilized projectiles. The code name of the new program is SPIN-73.

The starting point for the current study was the computer program SPINNFR[70*] which was developed at Picatinny Arsenal during the period from September 1966 to October 1968. This program was modified by General Electric in 1969[68] and 1970[71] to update the predictions of the drag coefficient and also to perform a closed form dispersion analysis.

In general the method used during the development of the original Spinner was as follows:

Basic projectile configurations were selected which were considered by Whyte[68,70] to have well determined aerodynamic coefficients. Empirical equations and constants were developed, by a trial and error process, by which the standard coefficients could be adjusted for changes in total length, nose length, boattail length and center of gravity.

The following limitations were and are present in the original program.

1. Nose length 1.8 to 4.0 calibers
2. Projectile length 3.6 to 9.0 calibers
3. Boattail length 0.0 to 1.0 calibers
4. Meplot diameter, 0.10 to 0.15 calibers
5. Nose radius, secant +100% to secant -30%
6. Rotating band diameter, 1.025 calibers

* References alphabetically listed starting on page 22.

However as most projectiles in service and under investigation during the period from 1966 to 1969 in general fell within the above bounds the limitations of the program were not considered very serious.

Since 1970 several programs have been initiated by the Army and Navy which are considering utilizing projectiles with nose lengths of up to 5.5 calibers and boattail lengths of up to 2.5 calibers.

Also payload and fuzing capabilities of several small arms projectiles currently under development by the Air Force, Navy, and Army have dictated blunter ogives (large meplats) and near tangent ogives.

Rotating band diameter are also of larger scale on small arms than corresponding shapes of large calibers thereby complicating the prediction process.

Because of these known limitations and future requirements the need for a revised SPINNER was indicated. Thus this current study was initiated in August 1972.

Sears[60] of Eglin in 1972 published a computerized curve fit technique for predicting the drag of projectile. His results indicated improvement over the original SPINNER in the area of tangent ogives and meplat bluntness.

A similar method to that used by Sears was employed in updating SPINNER. In discussing the computer programs the 1969 version of SPINNER will be referred to as SPIN-69 and the 1973 version as SPIN-73.

PROCEDURE

The most difficult task in the analysis of data is determining a constant accurate model which will adequately curve fit data under all circumstances, whereupon predictions of results under a different sets of initial conditions do not result in completely useless answers.

An example of useless results is shown in figure 15 where the predicted axial force is negative in the SPIN-69 program. When terms of higher order polynomials are employed to obtain good fits one must be very cautious when using these polynomials to extrapolate or even interpolate data. These cautions are pointed out because SPIN-73 does employ higher order polynomials.

The equations used for fitting and probable errors will be covered for each coefficient individually.

In general the data utilized with very few exceptions was obtained from reports published by the Ballistic Research Laboratory (BRL) and Arnold Engineering Development Center (AEDC). No wind tunnel data was used at all in the data bank. Wind tunnel data was used to determine trends and comparisons were made with the trends resulting data fitting.

The references utilized to collect the experimental data are listed starting on page 22. Unpublished data from BRL, Picatinny, AEDC and GE were also used. The method used to curve fit the data is described briefly in Appendix A.

Equations of the following general form were used for all coefficients. Definitions of VL, VN, VB, VCG, BD, DM, OR, and BOOM are found in figure 1.

$$
\begin{aligned}
C_X = a_1 &+ a_2\ (CVN) + a_3\ (CVN^2) \\
&+ a_3\ (CXCL) + a_4\ (CXCL^2) \\
&+ a_5\ (CVN \cdot CXCL) \\
&+ a_6\ (CVB) + a_7\ (CBD) \\
&+ a_8\ (CMK) + a_9\ (CMK^2) \\
&+ a_{10}\ (CVN \cdot CMK) + a_{11}\ (CXCL \cdot CMK) \\
&+ a_{11}\ (CRAT) + \text{---}\ \ \text{etc.}
\end{aligned}
$$

where:

$$
\begin{aligned}
CVN &= VN - 2.5 \\
CXCL &= VL - VN - VB - 1.5 \\
CVB &= VB \\
CBD &= BD - 1.02 \\
CMK &= CMK - 1.05 \\
CRAT &= VN^2/OR - 0.40
\end{aligned}
$$

The combinations, variations, and parameters which can be included in the fitting equation are nearly infinite. References such as Dickenson,[19-28] Sears,[60] Watt,[66] and Murphy[43] were used as guides for determining the most effective way of deriving an empirical equation. By the trial and error process equations of the above type were manipulated into a form which adequately described the experimental data.

EMPIRICAL EQUATIONS

This section will describe individually for each coefficient the equations contained in the computer program SPIN-73 as of June 1973.

Axial Force Coefficient

CXCL = VL - VN - VB - 1.5

CBD = DB - 1.02

CDM = $(DM - 0.12)^2$ CRAT = $VN^2/OR - 0.40$

if $0 < VN < 3.0$ set VNX = VN , DXN = 0.0

if $0 < CXCL < 1.5$ set CXCLL = CXCL , DXCL = 0.0

if $0.2 < VB < 0.65$ set VBX = VB - 0.2 DXBT = 0.0

If VN, CXCL, or VB are greater than the maximum

set VNX = 3.0 , DXN = (VN - 3.0) A_{13}

CXCLL = 1.5 ,DXCL = (CXCL - 1.5) 0.01

VBX = 0.45 ,DXBT = (VB - 0.65) A_{10}

If VB is less than the minimum

VBX = 0.0 , DXBT = 0.0

$$
\begin{aligned}
C_X = {} & a_1 + a_2 (VNX - 2.5) + a_3 (VNX - 2.5)^2 \\
& + a_4 (VNX - 2.5)^3 + a_5 (CXCLL) + a_6 (CXCLL)^2 \\
& + a_7 (VBX) + a_8 (CRAT) + a_9 (CRAT)^2 \\
& + a_{11} (CBD) + a_{12} (CDM) - (BOOM/1.36)^2\ 0.01 \\
& - DXBT - DXN + DXCL
\end{aligned}
$$

The "IF" statements are required to circumvent the need for higher order polynomials in the equations. In this manner only linear extrapolation and interpolations are allowed on the fringes of the program capabilities. This should prevent completely erroneous estimates.

Normal Force Coefficient Derivative, Pitching Moment Coefficient Derivative and Normal Force Center of Pressure

if $0 < VN < 3.0$ set $VNX = VN$, $DNX = 0.0$

if $0 < VB < 1.0$ set $VBNP = VB^{A}$, $VBMP = VB^{B}$, $VBX = VB$

where: Subsonic $A = 1.0$, $B = 0.8$

Supersonic $A = 1.5$, $B = 1.0$

if VN or VB are greater than the maximum

set $VNX = 3.0$, $DNX = VN - 3.0$

$VBX = 1.0$, $VBNP = VB^{0.5}$, $VBMP = VB^{0.5}$

Now set

$CVNN = VNX - 2.47$

$CXLL = VL - VN - VB - 2.15$

$CDMM = DM - 0.17$

$CBBD = BD - 1.04$

$CCRT = VN^{2}/OR - 0.48$

$VBTT = CVL/4.7$

$$CNAB = B_1 + B_2\ (CVNN) + B_3\ (CXLL) + B_4\ (CCRT) + B_5\ (CVNN)^2 + B_6\ (CXLL)^2$$

$$CNBT = B_7\ (VBNP) + B_8\ (VBX \cdot CVNN) + B_9\ (VBX \cdot CXLL)$$

$$CNAT = CNAB + CNBT$$

$$AMOMSQ = CNAB\ [C_1 + C_2\ (CVNN) + C_3\ (CVNN)^2$$
$$+ C_4\ (CVNN)^3 + C_5\ (CXLL) + C_6\ (CXLL)^2$$
$$+ C_7\ (CXLL)^3 + C_8\ (CCRT) + C_9\ (CCRT)^2$$
$$+ C_{10}\ (CDMM) + C_{11}\ (CCRT \cdot CYNN) + C_{17}\ (DNX)]$$

$$AMOMBT = VBTT\ [C_{12}\ (VBMP) + C_{13}\ (VBX \cdot CVNN)$$
$$+ C_{14}\ (VBX \cdot CXLL) + C_{15}\ (VBX \cdot CCRT)$$
$$+ C_{16}\ (VBX \cdot CCRT \cdot CVNN)]$$

$$CPN = (AMOMSQ + AMOMBT)/CNAT$$

$$C_{N_\alpha} = CNAT$$

$$C_{M_\alpha} = (VCG - CPN)\ C_{N_\alpha}$$

Yaw Axial Force Coefficient

$$CXCL = VL - VN - VB - 1.5$$

$$CRAT = VN^2/OR - 0.40$$

$$CVB = VB$$

$$C_{X_2} = D_1 + D_2\ (CXCL) + D_3\ (CRAT) + D_4\ (CVB) - C_{N\alpha}$$

The Yaw Drag coefficient may be computed by adding C_{X_2} and $C_{N\alpha}$.

Magnus Force Coefficient Derivative, Magnus Moment Coefficient Derivative, Magnus Force Center of Pressure

$$CVL = VL$$

$$CVB = VB$$

$$CXCL = VL - VN - VB - 1.5$$

$$CVN = VN - 2.5$$

$$CYPA = E_1 \; (CVL) - 0.1 \; (CVB)$$

at $\bar{\alpha} = 1.0°$

$$CNPAN = -E_1 \; (CVL) \; [E_2 + 0.55 \; (CXCL) + 0.80 \; (CVN)] + CVB \; (CVL/4.7)$$

$$CPF_{(1)} = -CNPAN/CYPA$$

$$C_{Y_{p\alpha}} = CYPA$$

$$C_{n_{p\alpha(1)}} = (VCG - CPF_{(1)}) \; C_{Y_{p\alpha}}$$

at $\bar{\alpha} = 2.0°$

$$CNPAN = -E_1 \; (CVL) \; [E_3 + 0.55 \; (CXCL) + 0.80 \; (CVN)] + CVB \; (CVL/4.7)$$

$$CPF_{(2)} = -CNPAN/CYPA$$

$$C_{Y_{p\alpha}} = CYPA$$

$$C_{n_{p\alpha(2)}} = (VCG - CPF_{(2)}) \; C_{Y_{p\alpha}}$$

at $\bar{\alpha} = 5.0°$

$$CNPAN = -E_1 \; (CVL) \; [E_4 + 0.55 \; (CXCL) + 0.80 \; (CVN) + CVB \; (CVL/4.7)$$

$$CPF_{(5)} = -CNPAN/CYPA$$

$$C_{Yp\alpha} = CYPA$$

$$C_{n_{p\alpha}(5)} = (VCG - CPF_{(5)})\ C_{Yp\alpha}$$

Damping Moment Coefficient

$$CLL = VL - 5.0$$

$$CCG = VCG - 3.0$$

$$CVB = VB$$

$$C_{m_q} = -5.093\ [F_1 + F_2\ (CLL) + F_3\ (CLL^2) + F_4\ (CCG) + F_5\ (CCG)\ (CLL) + F_6\ (CCG)\ (CLL^2) + F_7\ (CCG)\ (CVB) + F_8\ (CVB)]$$

Spin Deceleration Coefficient

$$C_{l_p} = G1\ (VL/5.51)$$

Stability Analysis

The methods used for stability computations were extracted from references 44 and 45. They are identical to those contained in the original SPINNER.

Gyroscopic Stability Factor, s_g

$$s_g = 2I_x^2 p^2/\pi I_{y\rho}\ C_{m_\alpha}\ d^3\ V^2$$

Dynamic Stability Factor, s_d

$$s_d = \frac{2(C_{N_\alpha} - C_X + (k_1^{-2}/2)\ C_{n_{p\alpha}})}{(C_{N_\alpha} - C_X - (k_2^{-2}/2) C_{m_q} + (k_1^{-2}/2)\ C_{l_p})}$$

Nutation, Precession Frequencies $\omega_{1,2}$

$$\omega_{1,2} = \frac{pI_x}{2I_y} \; (1 \pm \sigma)$$

Nutation, Precession Yaw Damping Rates, $\lambda_{1,2}$

$$\lambda_{1,2} = \frac{\rho A}{4m} \left[-C_{N_\alpha} \; (1 \pm \frac{1}{\sigma}) + (k_2^{-2}/2) \; (1 \pm \frac{1}{\sigma}) \; C_{m_q} \pm (k_1^{-2}/\sigma) \; C_{n_{p\alpha}} \right]$$

where

$$k_1^{-2} = md^2/I_x$$

$$k_2^{-2} = md^2/I_y$$

$$\sigma = \sqrt{1 - 1/s_g}$$

The dispersion (DISP) is the radius in mils of a circle which a projectile will impact in a vertical plane when disturbed to a first maximum yaw angle of 5 degrees or less. The basis for this calculation is derived in Reference 71.

The time step (DELT) shown will provide 20 integrations per nutation cycle. This is entirely adequate for a 4th Order Range Kutta integrator.

RESULTS AND DISCUSSIONS

The results of several test cases are presented in Figures 2 thru 15. Plotted are experimental points, SPIN-69 and SPIN-73 results. Tabulated outputs of SPIN-73 are shown as tables 2 thru 15.

The following ranges of parameters are demonstrated by the test cases.

Total length	3.8 thru 10.0 calibers
Nose length	1.6 thru 5.5 calibers
Boattail length	0.0 thru 1.0 calibers
Ogive radius	tangent thru conical
Meplat diameter	0.0 thru 0.26 calibers
Band diameter	1.00 thru 1.05 calibers

In general the correlations between SPIN-73 and the experimental data is very good with noticeable improvements over SPIN-69. Most of the effort during this current study has been directed at the Axial Force and Pitching Moment correlations as these two coefficients are by far the most accurately determined during the experimental process. Much work still remains to be done on these coefficients in terms of defining a more adequate empirical model.

The most poorly determined coefficients remain the Magnus and damping. It is this author's opinion that the SPIN-73 improvement in these the calculations is negligible. While some new data has been published since 1968, in general data was previously available on similar shapes. For example the projectiles refered to as the XM380 and XM549 were experimentally

investigated long ago as the T388 and T387. This data was available in 1967 and had been included in the original (SPIN-69) program.

The bulk of the data published by AEDC through calendar year 1972 is suspect as far as the Magnus and damping coefficient are concerned because the effect on linear theory reductions of a slowly varying pd/2V was not taken into account.

This author also found in several instances as did Sears that the geometric description of the projectiles under test were not available either in the data reports or the data files.

The probable errors to the experimental data of the SPIN-73 empirical equations are shown in Table 1. The number of data points used to compute the probable error is shown in parenthesis.

CONCLUSIONS AND RECOMMENDATIONS

The SPIN-73 program has been shown through test cases to be more accurate than the SPIN-69 program.

The updating of SPIN-73 should be continued as new data is accumulated.

Records should be kept of shortcomings and extremely poor predictions.

Data should be more carefully reported with respect to actual configuration tested.

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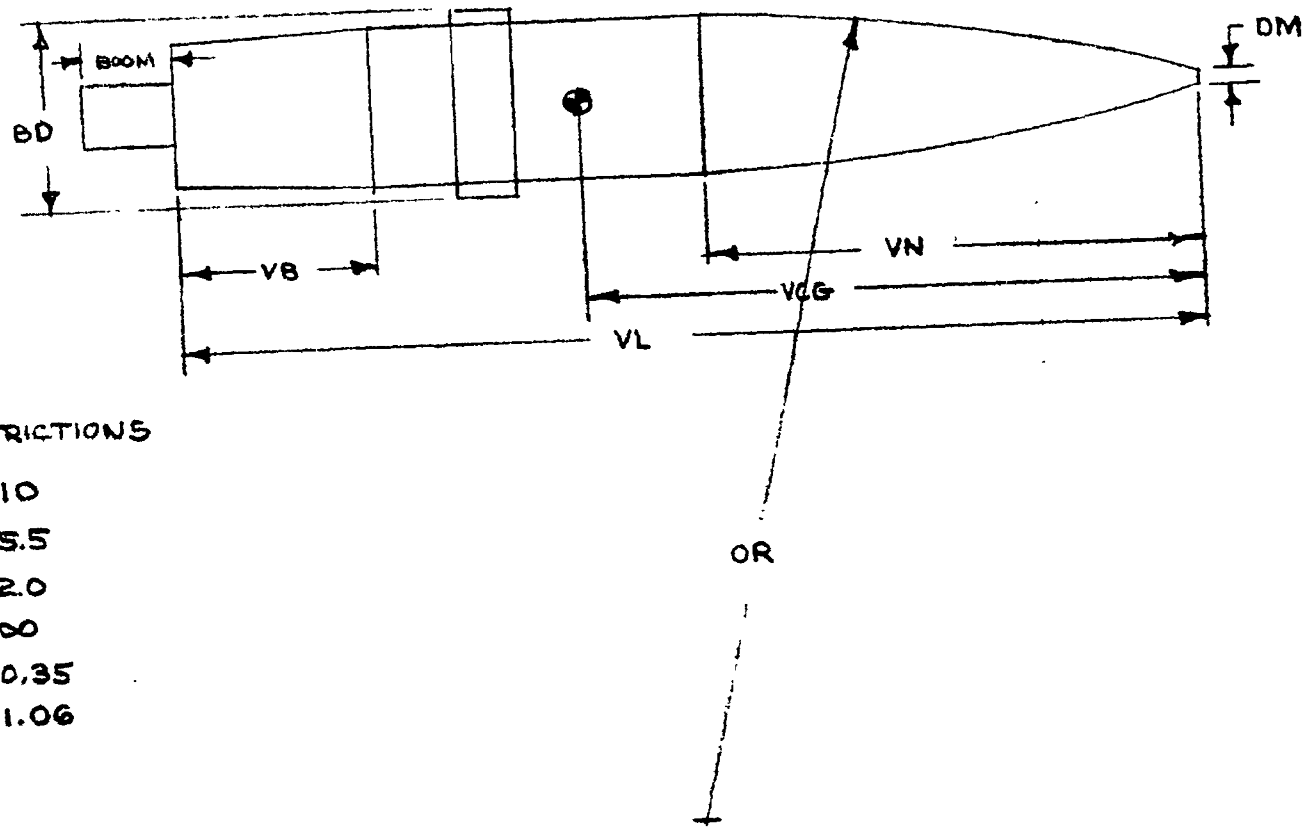


DIMENSION RESTRICTIONS

$2.5 < VL < 10$

$1.2 < VN < 5.5$

$0.0 < VB < 2.0$

$VN < OR < \infty$

$0.0 < DM < 0.35$

$1.0 < BD < 1.06$

PROJECTILE PARAMETERS - INPUT/OUTPUT

FIGURE 1

COEFFICIENT PROBABLE ERRORS

	e_{C_x}	$e_{C_{N\alpha}}$ SQ BASE	$e_{C_{N\alpha}}$ BOATTAIL	$e_{C_{m\alpha}}$ SQ BASE	$e_{C_{m\alpha}}$ BOATTAIL	$e_{C_{mq}}$	$e_{C_{np\alpha}}$
0.80	0.0078 (84)*	0.06 (86)	0.10 (37)	0.15 (90)	0.11 (39)	3.0 (78)	0.18 (72)
0.90	0.0090 (62)	0.06 (86)	0.10 (37)	0.15 (90)	0.11 (39)	—	—
0.95	0.0092 (56)	0.06 (86)	0.11 (49)	0.15 (90)	0.12 (53)	—	0.16 (72)
1.05	0.0076 (111)	0.09 (129)	0.10 (49)	0.13 (138)	0.10 (54)	3.0 (78)	—
1.10	0.0076 (111)	0.09 (129)	0.10 (49)	0.13 (138)	0.10 (54)	—	0.16 (72)
1.20	0.0076 (145)	0.09 (129)	0.09 (64)	0.13 (138)	0.14 (71)	—	0.12 (59)
1.50	0.0078 (193)	0.09 (129)	0.08 (52)	0.13 (138)	0.15 (58)	3.0 (63)	0.12 (59)
2.00	0.0078 (194)	0.09 (132)	0.07 (50)	0.12 (141)	0.17 (58)	3.0 (63)	0.12 (59)
2.50	0.0072 (159)	0.09 (132)	0.06 (38)	0.12 (141)	0.17 (45)	—	0.12 (59)
3.00	0.0072 (159)	—	—	—	—	—	—

* NO. OF DATA PTS. INCLUDED IN FIT

TABLE 1

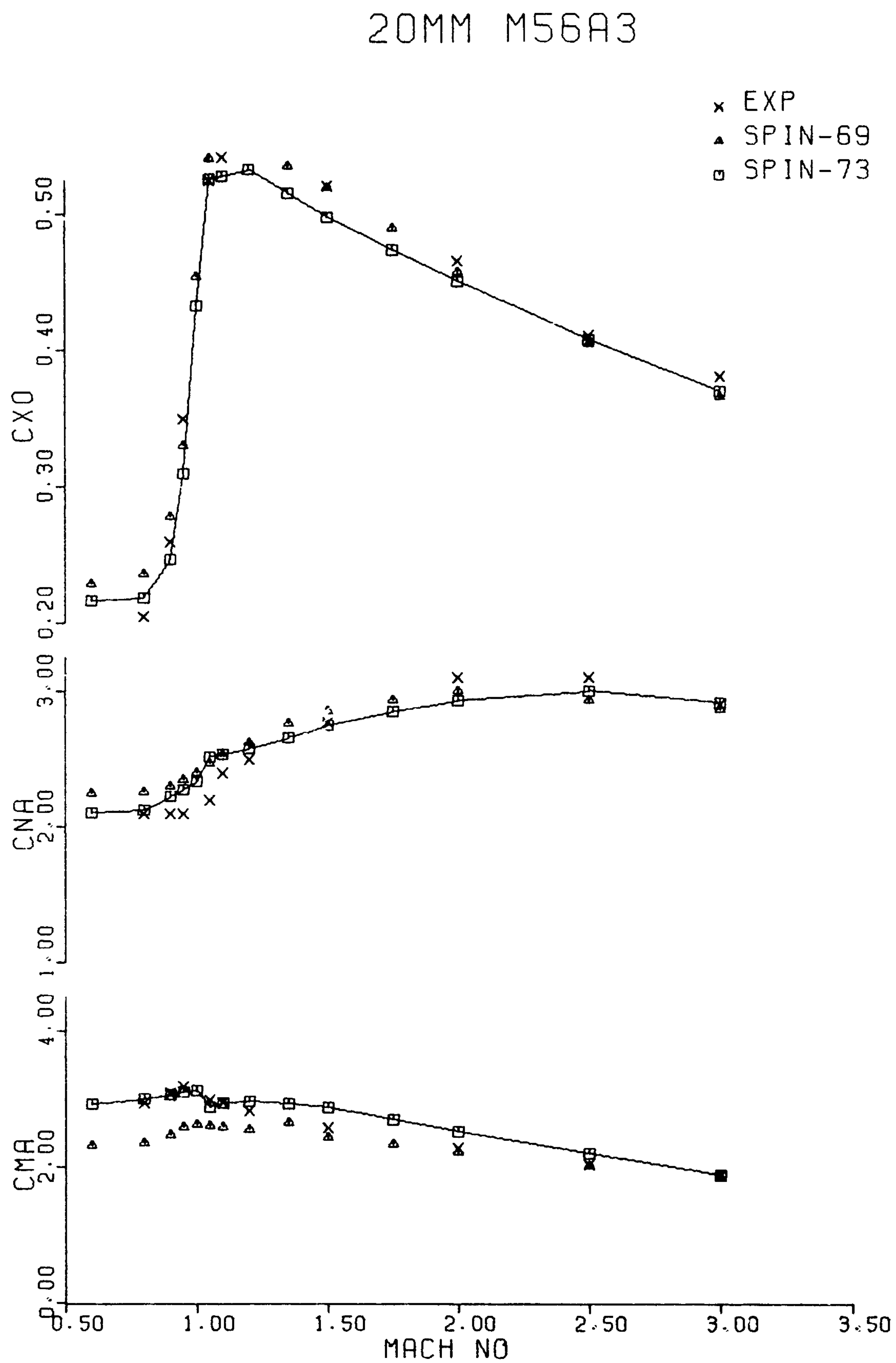
GE BURLINGTON VERMONT
M56A[illegible]

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
3.822	[illegible]	0.000	2.200	0.200	1.050	10.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	0.[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CMM	CYPA	CNPA	CNPA3	CNPA5	CPF=1	CPF=5	CNPA=5	CMQ	CLP
0.010	0.217	2.531	2.106	2.722	0.472	-.611	-.479	74.286	-705.356	1.476	2.576	0.193	-3.822	-.075
0.600	0.217	2.511	2.106	2.943	0.462	-.611	-.479	74.286	-705.356	1.476	2.576	0.193	-3.822	-.075
0.800	0.219	2.997	2.126	3.014	0.442	-.611	-.357	67.494	-637.444	1.676	2.676	0.254	-3.822	-.074
0.900	0.247	3.39[illegible]	2.228	3.072	0.481	-.646	-.177	49.243	-454.937	2.076	2.726	0.370	-6.379	-.070
0.950	0.310	3.51[illegible]	2.243	3.122	0.491	-.879	0.102	30.612	-340.822	2.376	2.776	0.453	-9.135	-.018
1.000	0.433	4.271	2.344	3.149	0.916	-.802	0.173	26.323	-225.733	2.476	2.776	0.414	-13.624	-.017
1.050	0.526	4.616	2.521	2.908	1.106	-.726	0.229	19.712	-119.622	2.576	2.776	0.379	-13.695	-.017
1.100	0.528	5.123	2.536	2.963	1.093	-.688	0.252	11.043	-72.933	2.626	2.776	0.355	-14.976	-.016
1.200	0.533	5.631	2.585	2.900	1.103	-.611	0.242	7.733	-39.827	2.656	2.776	0.315	-15.993	-.016
1.350	0.515	5.257	2.650	2.947	1.153	-.611	0.254	6.374	-26.244	2.676	2.776	0.315	-15.585	-.016
1.500	0.497	4.463	2.753	2.871	1.217	-.611	0.260	5.695	-19.453	2.686	2.776	0.315	-13.582	-.016
1.750	0.473	3.867	2.849	2.698	1.313	-.611	0.266	5.016	-12.662	2.696	2.776	0.315	-13.582	-.016
2.000	0.450	3.284	2.932	2.529	1.400	-.611	0.273	4.337	-5.871	2.706	2.776	0.315	-13.582	-.015
2.500	0.407	2.747	2.998	2.197	1.527	-.611	0.279	3.658	0.920	2.716	2.776	0.315	-13.582	-.015
3.000	0.369	2.308	2.915	1.889	1.612	-.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.014
4.000	0.331	1.887	2.815	1.909	1.582	-.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.014
5.000	0.309	1.465	2.715	1.922	1.552	-.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.013



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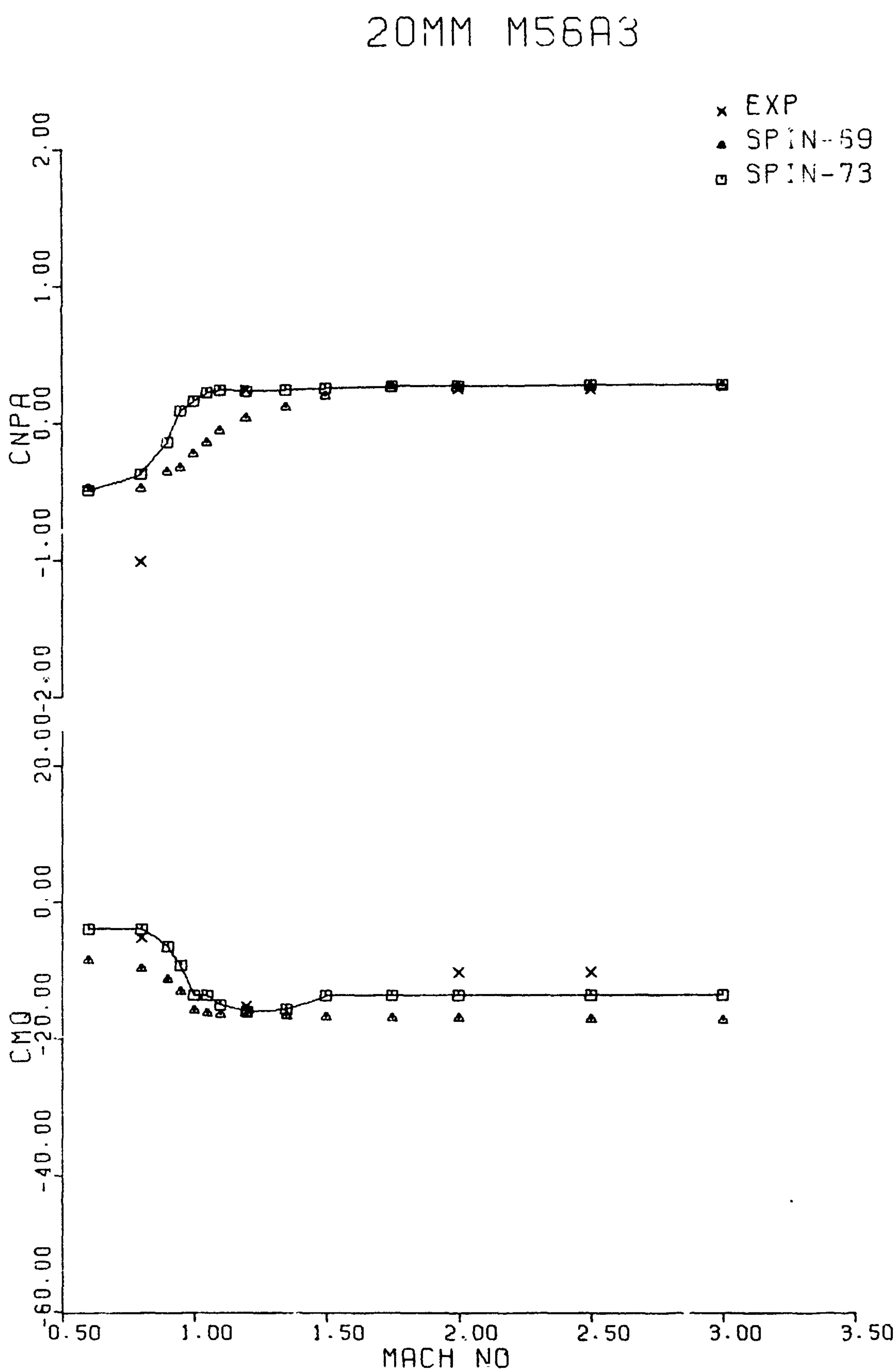
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MACH NO

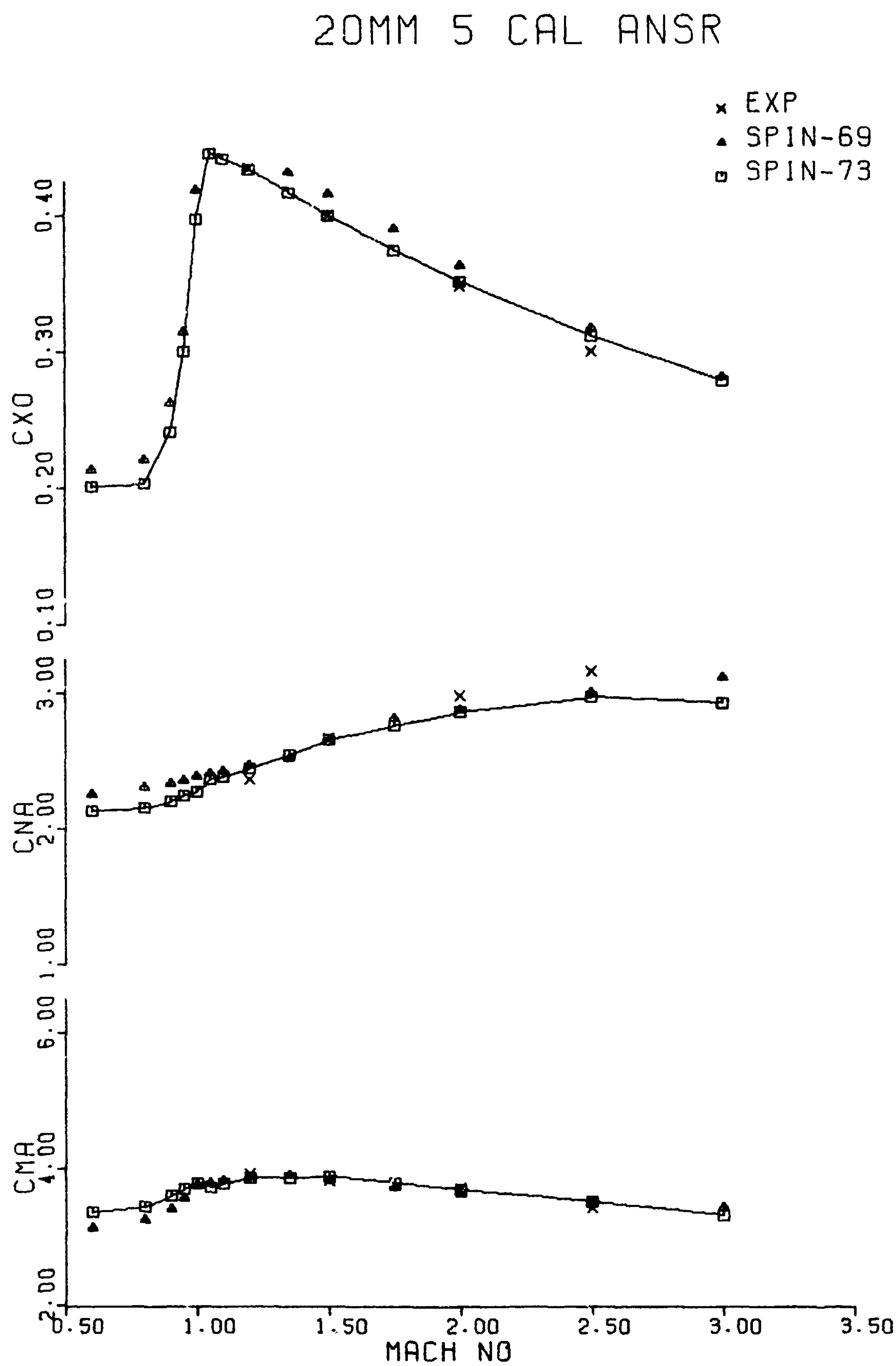
[illegible] INGTON [illegible]
5 CAL

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
5.000	2.00[illegible]	0.000	3.040	0.000	[illegible]	8.000	0.000

DIAMETER INCHES	IX LB-IN-S2	IY LB-IN-S2	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	0.[illegible]	0.000	[illegible]	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	[illegible]	CYPA	CNPA	CNPA3	CNPA5	[illegible]	[illegible]	[illegible]	CMQ	CLP
0.010	0.232	2.765	2.140	3.342	1.469	-.800	-.452	97.361	-936.111	2.225	3.325	0.228	-8.088	-.033
0.600	0.232	2.765	2.140	3.343	1.459	-.800	-.452	97.361	-936.111	2.225	3.325	0.228	-8.088	-.033
0.800	0.234	3.255	2.180	3.458	1.439	-.800	-.492	88.472	-847.222	2.425	3.425	0.388	-8.088	-.031
0.900	0.242	3.71[illegible]	2.215	3.621	1.404	-.900	-.194	64.583	-608.333	2.825	3.475	0.391	-11.113	-.026
0.950	0.331	4.187	2.248	3.773	1.384	-1.150	0.098	50.694	-469.444	3.125	3.525	0.558	-14.020	-.023
1.000	0.398	4.735	2.285	3.868	1.374	-1.050	0.194	34.583	-308.333	3.225	3.525	0.509	-18.459	-.022
1.050	0.446	5.232	2.373	3.743	1.463	-.950	0.271	20.694	-169.444	3.325	3.525	0.461	-18.919	-.022
1.100	0.442	5.798	2.394	3.808	1.440	-.900	0.301	14.583	-108.333	3.375	3.525	0.416	-20.963	-.021
1.200	0.434	6.305	2.455	3.872	1.403	-.800	0.292	10.250	-65.000	3.405	3.525	0.388	-23.020	-.021
1.350	0.417	5.834	2.546	3.889	1.513	-.800	0.308	8.472	-47.222	3.425	3.525	0.388	-24.599	-.021
1.500	0.430	5.197	2.658	3.894	1.575	-.800	0.316	7.583	-38.333	3.435	3.525	0.388	-26.211	-.021
1.750	0.374	4.589	2.761	3.868	1.461	-.800	0.324	6.694	-29.444	3.445	3.525	0.388	-26.211	-.020
2.000	0.351	3.996	2.864	3.781	1.748	-.800	0.332	5.806	-20.556	3.455	3.525	0.388	-26.211	-.020
2.500	0.311	3.361	2.969	3.514	1.856	-.800	0.340	4.917	-11.667	3.465	3.525	0.388	-26.211	-.019
3.000	0.278	2.827	2.975	3.329	1.902	-.800	0.348	4.028	-2.778	3.475	3.525	0.388	-26.211	-.018
4.000	0.240	2.335	2.825	3.300	1.872	-.800	0.348	4.028	-2.778	3.475	3.525	0.388	-26.211	-.018
5.000	0.218	1.853	2.725	3.245	1.842	-.800	0.348	4.028	-2.778	3.475	3.525	0.388	-26.211	-.017



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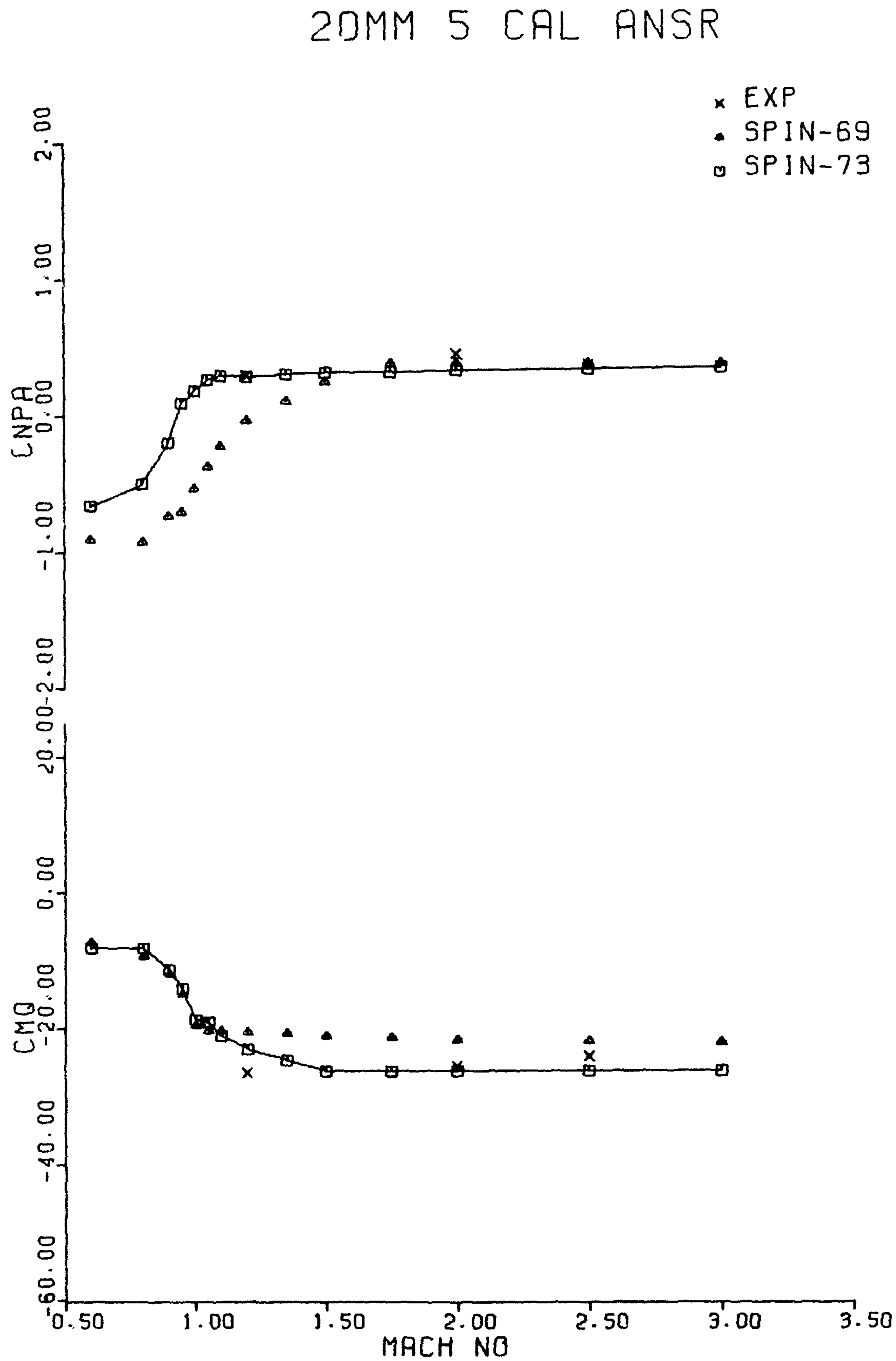
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1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

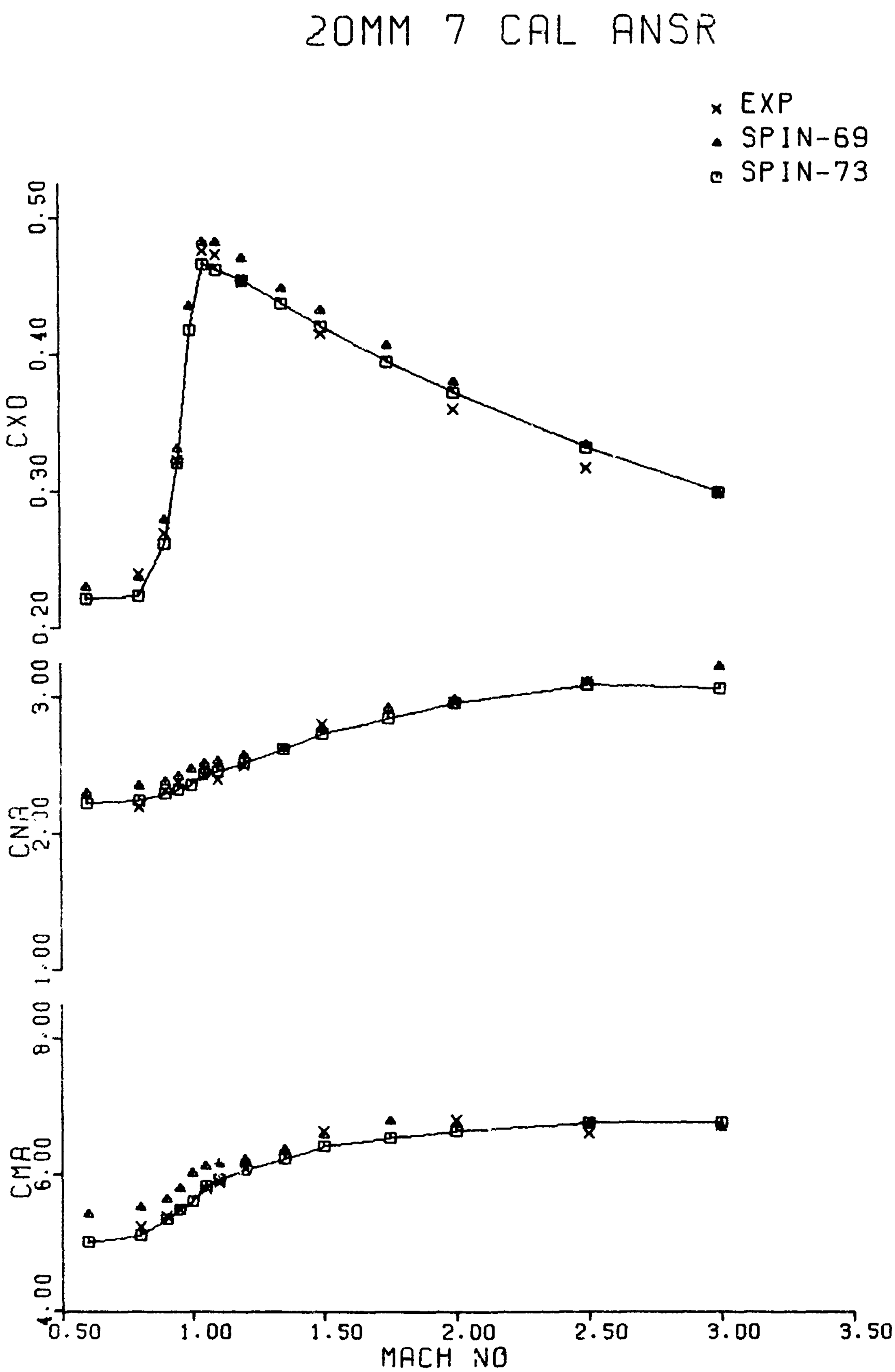
[illegible] BURLINGTON VERMONT
7 CAL

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
7.000	2.000	0.000	4.040	0.000	1.000	8.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	[illegible]	[illegible]	[illegible]	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CD0	CDA2	CLA	CMA	CPN	CYPA	CNPA	CMPAS	CLPAS	CPF-1	CPF-5	CNPAMS	CMQ	CLP
0.010	0.222	1.179	2.226	5.003	1.791	-1.120	-.801	136.472	-1327.777	3.325	4.425	0.431	-31.495	-.046
0.600	0.222	1.179	2.226	5.075	1.781	-1.120	-.801	136.472	-1327.777	3.325	4.425	0.431	-31.495	-.046
0.800	0.224	1.464	2.246	5.115	1.763	-1.120	-.577	124.028	-1202.778	3.525	4.525	0.543	-31.495	-.044
0.900	0.262	4.124	2.296	5.351	1.719	-1.260	-.145	90.583	-868.444	3.925	4.575	0.674	-34.826	-.037
0.950	0.421	4.607	2.326	5.495	1.678	-1.610	0.298	71.139	-673.889	4.225	4.625	0.942	-37.631	-.032
1.000	0.418	5.253	2.361	5.624	1.654	-1.470	0.419	48.583	-448.333	4.325	4.625	0.860	-42.168	-.030
1.050	0.460	5.869	2.436	5.811	1.644	-1.330	0.512	29.139	-253.889	4.425	4.625	0.778	-42.378	-.030
1.100	0.462	5.522	2.458	5.935	1.625	-1.260	0.548	20.583	-168.333	4.475	4.625	0.737	-45.703	-.030
1.200	0.454	5.328	2.522	6.088	1.624	-1.120	0.521	14.517	-107.667	4.505	4.625	0.655	-49.398	-.030
1.350	0.437	4.737	2.618	6.250	1.652	-1.120	0.543	12.028	-82.778	4.575	4.625	0.655	-54.523	-.029
1.500	0.420	4.116	2.734	6.416	1.651	-1.120	0.666	10.783	-70.333	4.635	4.725	0.767	-61.769	-.029
1.750	0.394	5.504	2.844	6.548	1.737	-1.120	0.790	9.539	-57.889	4.745	4.825	0.879	-63.769	-.029
2.000	0.371	4.895	2.955	6.637	1.794	-1.120	0.913	8.294	-45.444	4.855	4.925	0.991	-65.769	-.028
2.500	0.331	4.252	3.078	6.765	1.842	-1.120	0.924	7.050	-33.000	4.865	4.925	0.991	-67.769	-.027
3.000	0.298	3.594	3.051	6.753	1.827	-1.120	0.902	5.806	-20.556	4.845	4.895	0.958	-67.769	-.025
4.000	0.260	3.309	2.951	6.620	1.797	-1.120	0.879	5.806	-20.556	4.825	4.875	0.935	-65.769	-.025
5.000	0.238	2.424	2.851	6.482	1.767	-1.120	0.823	5.806	-20.556	4.775	4.823	0.879	-62.769	-.024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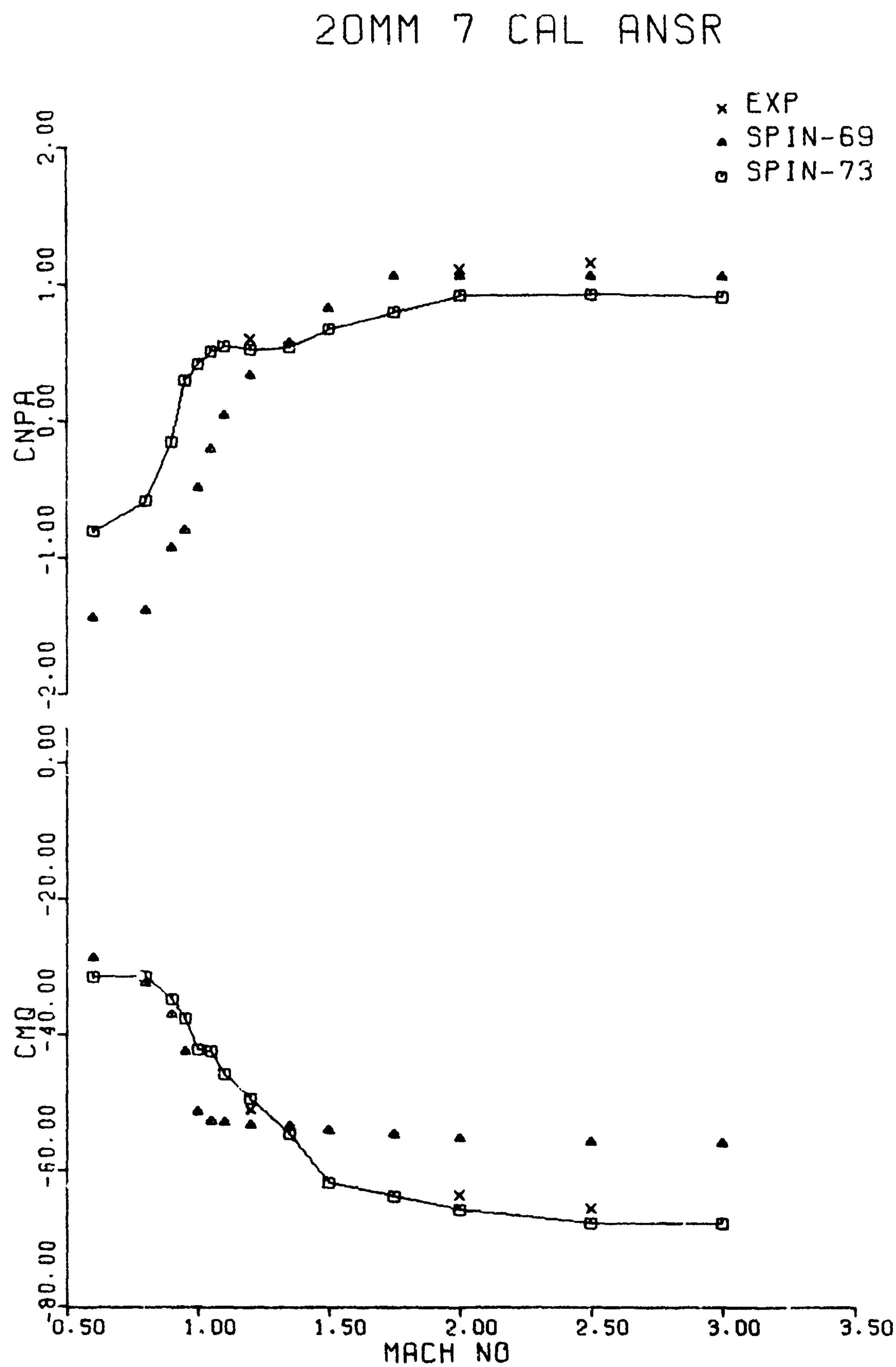

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1.50
2.00
2.50
3.00
3.50
MACH NO

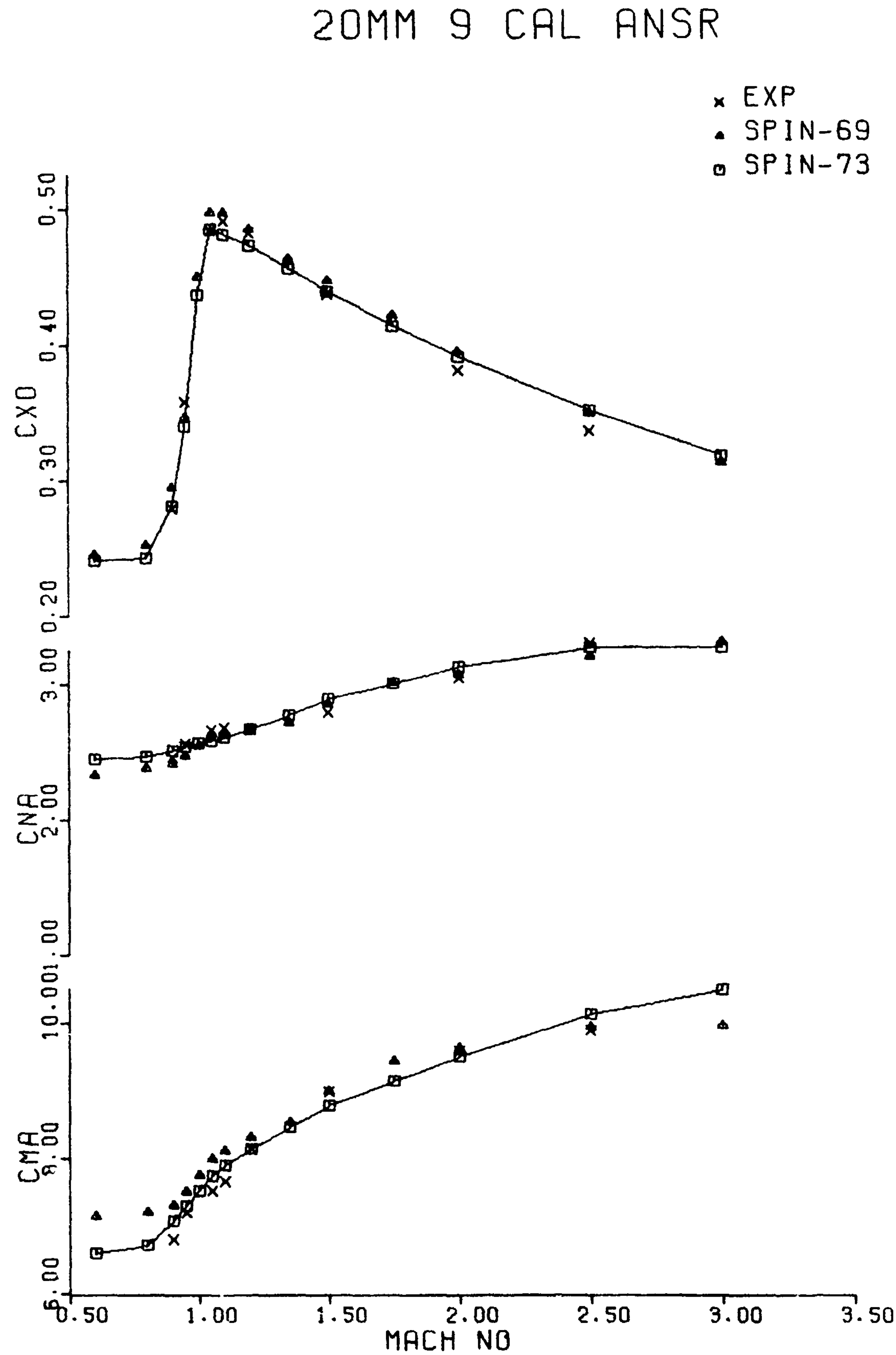
OF BURLINGTON VERMONT
9 CAL

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
9.000	2.000	0.000	5.050	0.000	1.000	8.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CPF*1	CPF*5	CNPA*5	CMQ	CLP
0.010	0.242	3.445	2.460	6.503	2.365	-1.440	-.900	175.583	-1716.333	4.425	5.525	0.684	-71.175	-.059
0.600	0.242	3.445	2.460	6.628	2.356	-1.440	-.900	175.583	-1716.333	4.425	5.525	0.684	-71.175	-.059
0.800	0.244	3.935	2.480	6.732	2.336	-1.440	-.612	159.583	-1558.333	4.625	5.625	0.828	-71.175	-.057
0.900	0.282	4.407	2.525	7.110	2.234	-1.670	-.041	116.583	-1128.333	5.025	5.675	1.012	-74.409	-.048
0.950	0.341	4.882	2.553	7.330	2.179	-2.070	0.569	91.583	-878.333	5.325	5.725	1.397	-76.706	-.041
1.000	0.438	5.635	2.585	7.537	2.135	-1.890	0.709	62.583	-588.333	5.425	5.725	1.276	-80.734	-.039
1.050	0.486	6.411	2.594	7.766	2.056	-1.710	0.812	37.583	-338.333	5.525	5.725	1.154	-80.487	-.039
1.100	0.482	7.173	2.617	7.913	2.027	-1.620	0.850	26.583	-228.333	5.575	5.725	1.093	-85.099	-.039
1.200	0.474	8.166	2.684	8.160	2.010	-1.440	0.799	18.783	-150.333	5.605	5.725	0.972	-90.441	-.038
1.350	0.457	7.566	2.784	8.475	2.006	-1.440	0.828	15.583	-118.333	5.625	5.725	0.972	-100.139	-.038
1.500	0.440	6.946	2.904	8.801	2.020	-1.440	1.274	13.983	-102.333	5.935	6.025	1.404	-114.066	-.038
1.750	0.414	6.336	3.014	9.170	2.008	-1.440	1.721	12.383	-86.333	6.245	6.325	1.836	-120.066	-.037
2.000	0.391	5.715	3.135	9.522	2.012	-1.440	2.167	10.783	-70.333	6.555	6.625	2.268	-126.066	-.036
2.500	0.351	5.055	3.275	10.140	1.954	-1.440	2.182	9.183	-54.333	6.565	6.625	2.268	-132.066	-.034
3.000	0.318	4.279	3.266	10.508	1.833	-1.440	2.066	7.583	-38.333	6.485	6.535	2.138	-132.066	-.033
4.000	0.280	3.594	3.166	10.281	1.803	-1.440	1.980	7.583	-38.333	6.425	6.475	2.052	-126.066	-.032
5.000	0.258	2.909	3.066	10.048	1.773	-1.440	1.764	7.583	-38.333	6.275	6.325	1.836	-117.066	-.031



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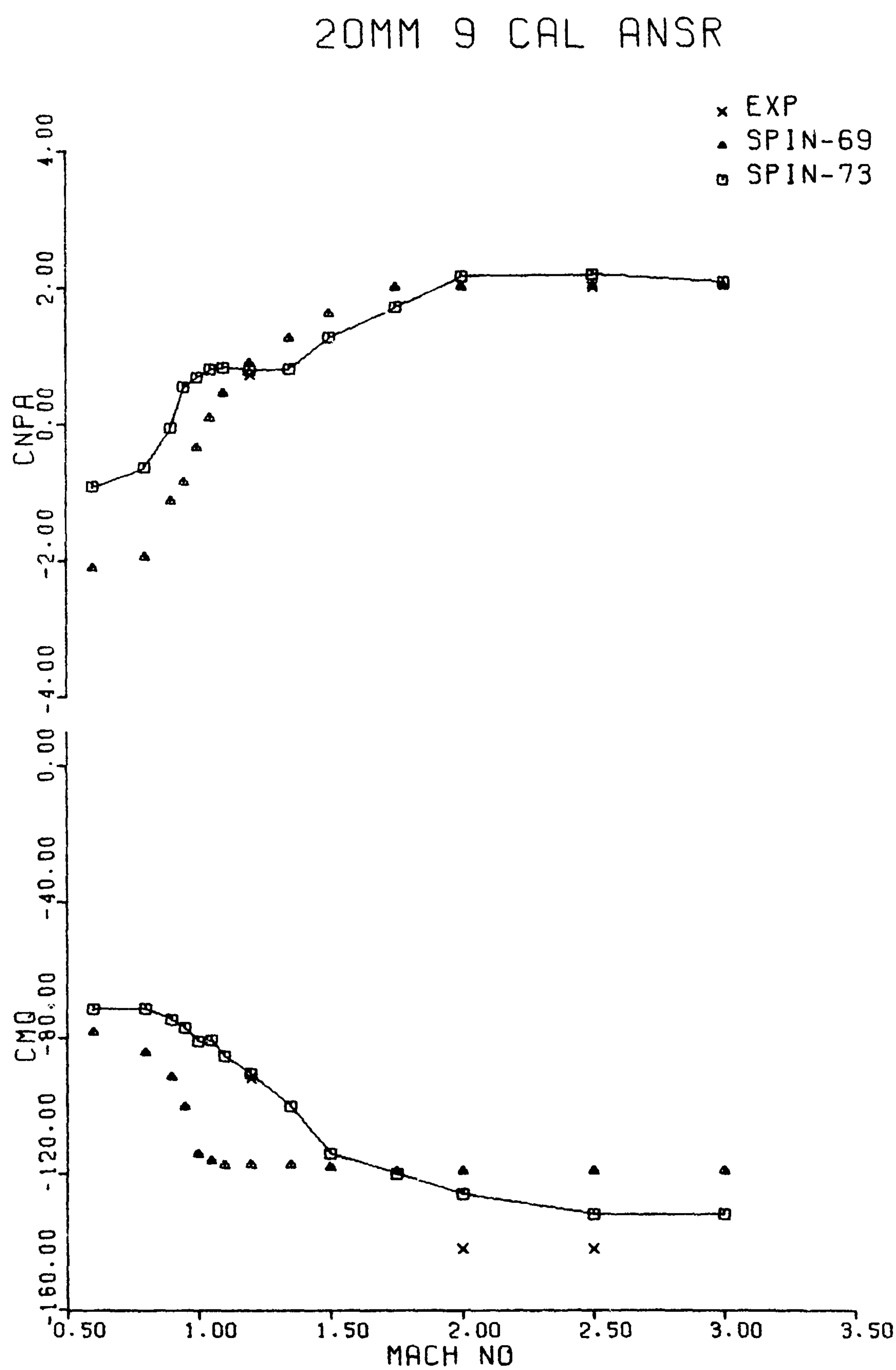
MACH NO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-120.00
-160.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

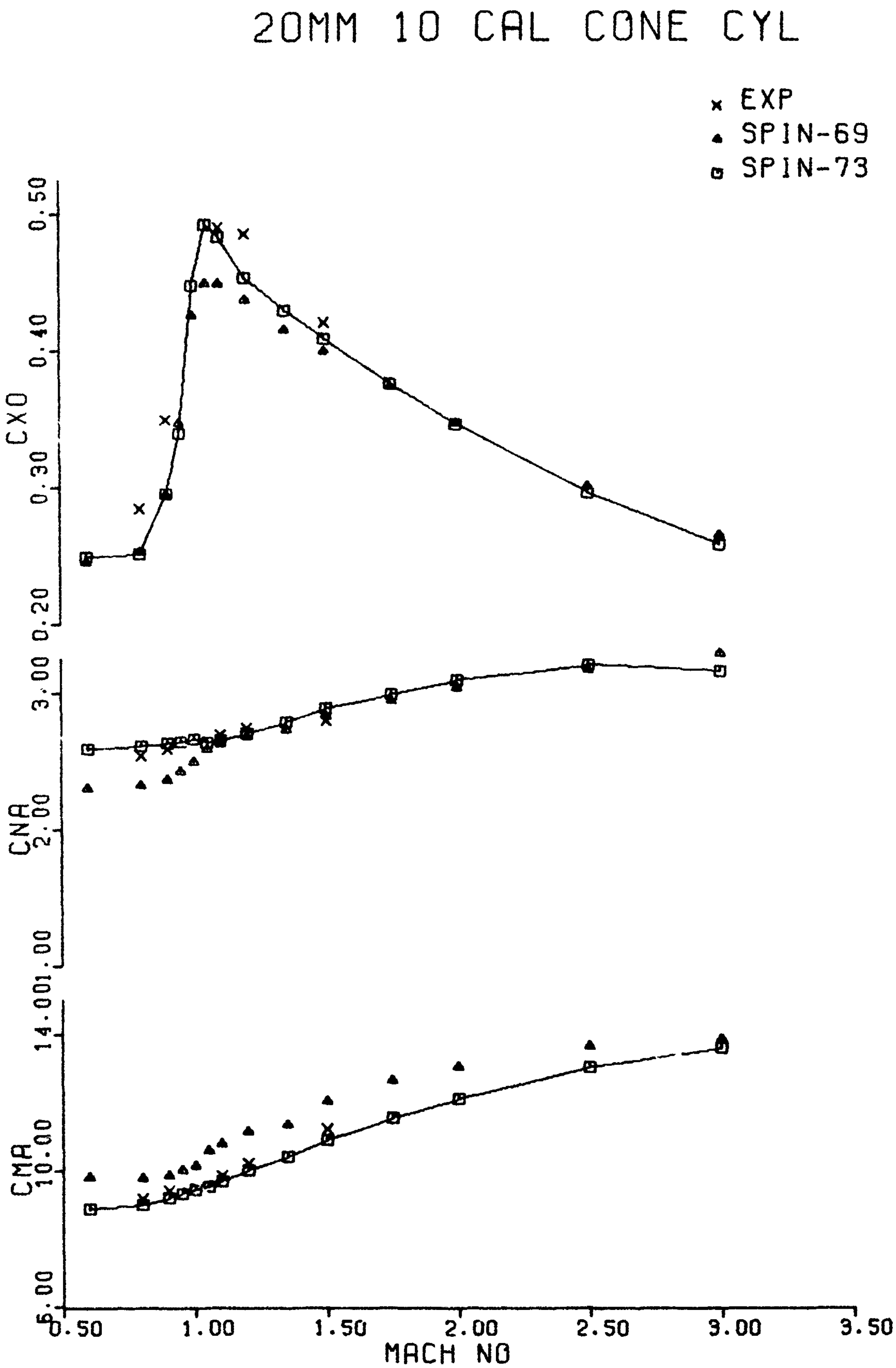
NEW INGICN SEGMENT
CONE CYL

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
10.000	2.836	0.000	6.747	0.009	1.000	1000.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LB	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CMQ	CYPA	CNPA	CNPA3	CNPA5	CPF-1	CPF-5	CNPA-5	CMQ	CLP
0.010	0.258	3.197	2.690	8.903	3.322	-1.600	-2.501	195.139	-1913.889	5.184	6.284	-.741	-37.685	-.066
0.600	0.250	3.190	2.603	8.929	3.317	-1.600	-2.501	195.139	-1913.889	5.184	6.284	-.741	-37.685	-.066
0.800	0.252	3.64[illegible]	2.620	9.090	3.292	-1.600	-2.181	177.363	-1736.111	5.384	6.384	-.591	-37.685	-.063
0.900	0.296	4.1[illegible]	2.637	9.210	3.247	-1.800	-1.733	179.583	-1256.111	5.784	6.434	-.583	-41.329	-.053
0.950	0.340	4.53	2.651	9.349	3.217	-2.300	-1.525	101.800	-980.556	6.084	6.484	-.605	-43.337	-.046
1.000	0.448	5.2[illegible]	2.670	9.447	3.193	-2.100	-1.182	69.583	-656.111	6.184	6.484	-.552	-47.080	-.044
1.050	0.497	6.027	2.642	9.546	3.126	-1.900	-.880	41.806	-380.556	6.284	6.484	-.500	-46.633	-.043
1.100	0.483	4.7[illegible]	2.658	9.716	3.084	-1.800	-.743	29.583	-258.333	6.334	6.484	-.473	-52.679	-.043
1.200	0.453	7.7[illegible]	2.710	10.045	3.060	-1.400	-.613	20.917	-171.667	6.344	6.434	-.421	-60.061	-.042
1.250	0.429	7.13[illegible]	2.708	10.440	2.994	-1.600	-.591	17.361	-136.111	6.384	6.484	-.421	-79.080	-.042
1.500	0.408	6.554	2.886	10.915	2.965	-1.600	0.079	15.583	-118.111	6.704	6.884	0.219	-97.872	-.042
1.750	0.375	5.947	2.994	11.507	2.883	-1.600	0.731	13.800	-100.556	7.284	7.284	0.899	-105.872	-.041
2.000	0.345	5.345	3.095	12.117	2.832	-1.600	1.387	12.078	-82.778	7.614	7.484	1.499	-113.872	-.040
2.500	0.295	4.82	3.198	13.087	2.665	-1.400	1.483	10.750	-65.000	7.674	7.684	1.499	-121.872	-.038
3.000	0.257	4.123	3.152	13.587	2.436	-1.600	1.227	8.472	-47.222	7.514	7.564	1.307	-121.872	-.036
4.000	0.219	3.479	3.052	13.248	2.406	-1.600	1.099	8.472	-47.222	7.434	7.484	1.179	-113.872	-.035
5.000	0.197	2.635	2.952	12.982	2.376	-1.600	0.779	8.472	-47.222	7.234	7.284	0.859	-101.872	-.034



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SPIN-73
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3.00
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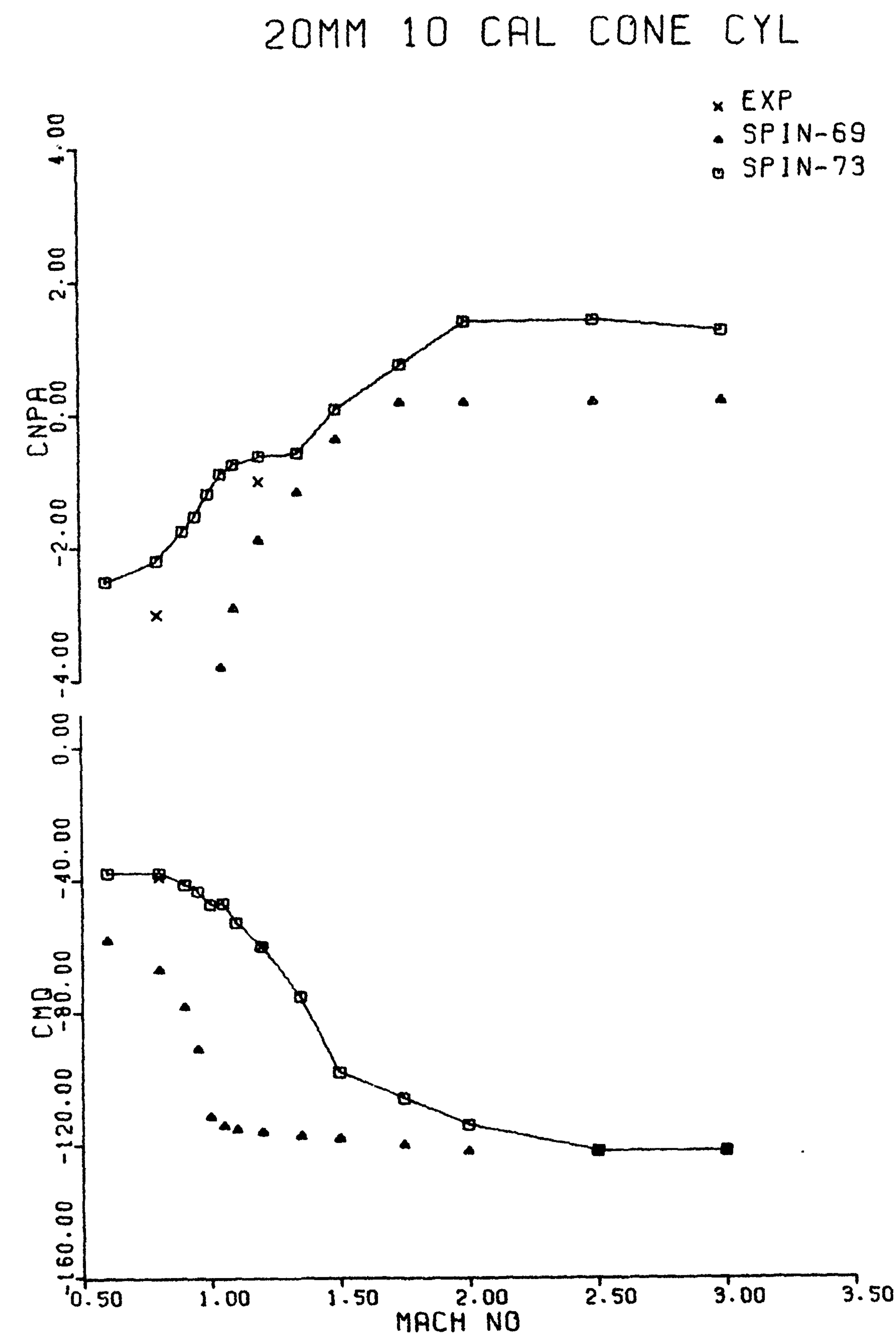
MACH NO



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-4.00
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-80.00
-120.00
-160.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

[illegible] VERSION
M1

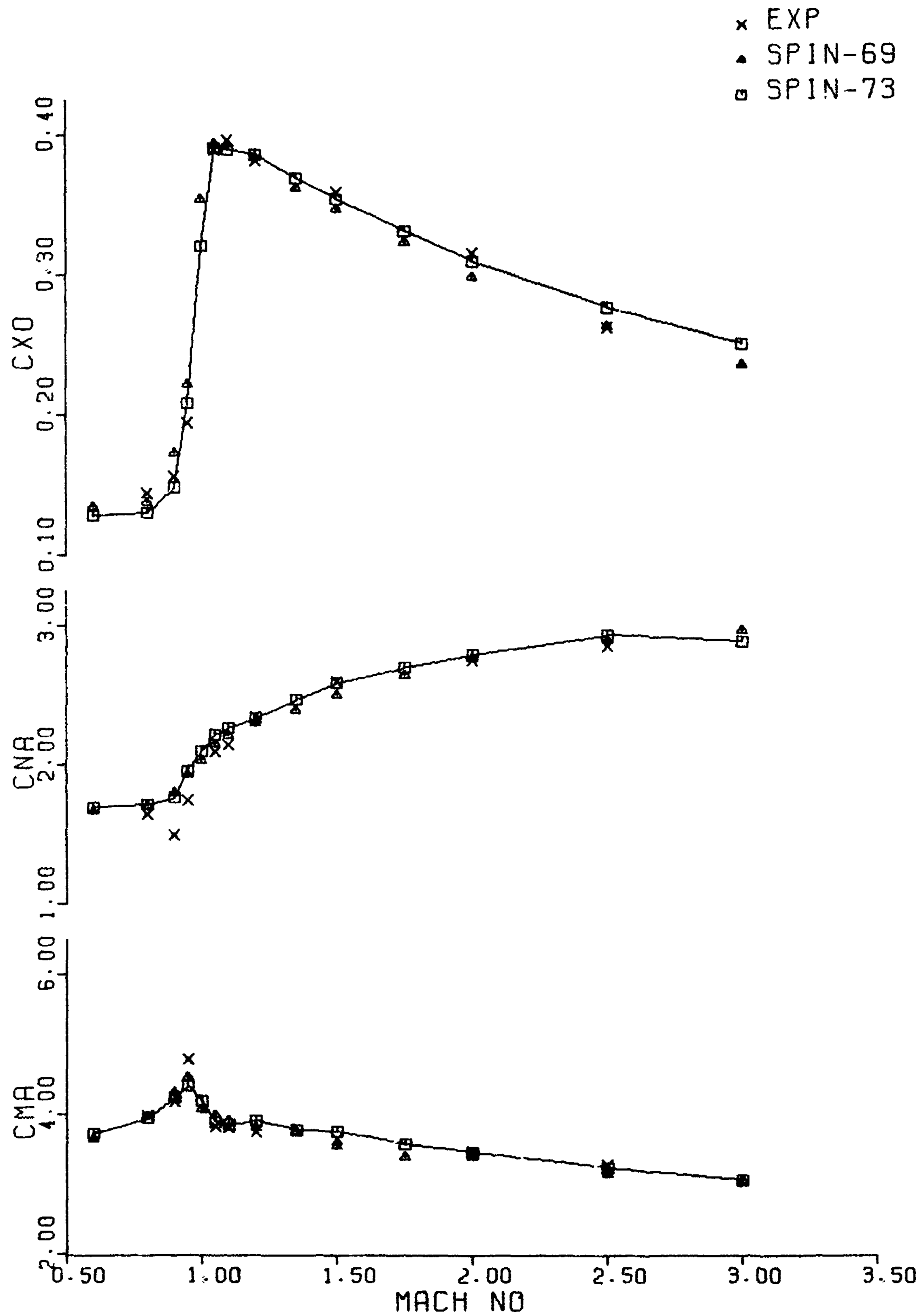
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
4.700	2.300	0.900	2.900	0.133	1.024	6.900	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CMPA3	CMPA5	CPF=1	CPF=N	CNPAMS	CMQ	CLP
0.010	0.127	2.551	1.471	3.939	0.629	-.802	-.491	91.494	-677.444	2.367	1.399	0.336	-7.495	-.031
0.600	0.127	2.551	1.473	3.948	0.612	-.802	-.491	91.494	-677.444	2.367	1.399	0.336	-7.495	-.031
0.800	0.129	3.371	1.493	4.170	0.512	-.802	-.341	83.119	-793.666	2.559	1.493	0.411	-7.495	-.030
0.920	0.145	3.617	1.745	4.471	0.417	-.896	-.089	60.683	-969.333	2.881	1.494	0.461	-9.746	-.025
0.950	0.333	4.221	1.927	4.635	0.474	-1.131	0.111	47.620	-638.778	3.080	1.462	0.546	-12.134	-.022
1.000	0.427	4.494	2.101	4.423	0.636	-1.037	0.211	32.603	-387.111	3.264	1.490	0.579	-15.998	-.020
1.050	0.409	5.624	2.147	4.131	1.074	-.941	0.333	19.420	-154.778	3.333	1.523	0.512	-15.476	-.020
1.100	0.435	5.58	2.222	4.003	1.138	-.896	0.376	13.683	-99.333	3.400	1.542	0.503	-16.798	-.020
1.200	0.403	6.137	2.307	4.069	1.316	-.802	0.396	9.410	-58.460	3.474	1.586	0.486	-18.002	-.020
1.350	0.389	5.527	2.437	3.889	1.384	-.802	0.411	7.939	-41.889	3.493	1.586	0.486	-17.697	-.020
1.500	0.374	4.941	2.573	4.012	1.421	-.802	0.419	7.103	-33.533	3.502	1.586	0.486	-17.299	-.020
1.750	0.351	4.374	2.690	3.891	1.533	-.802	0.426	6.260	-25.178	3.511	1.586	0.486	-17.299	-.019
2.000	0.330	3.824	2.790	3.832	1.607	-.802	0.434	5.432	-16.822	3.521	1.586	0.486	-17.299	-.019
2.500	0.293	3.099	2.912	3.759	1.699	-.802	0.441	4.597	-8.467	3.530	1.586	0.486	-17.299	-.018
3.000	0.261	2.587	2.903	3.595	1.742	-.802	0.449	3.741	-.111	3.540	1.586	0.486	-17.299	-.017
4.000	0.223	2.105	2.803	3.567	1.709	-.802	0.449	3.741	-.111	3.540	1.586	0.486	-17.299	-.017
5.000	0.201	1.444	2.703	3.524	1.676	-.802	0.449	3.741	-.111	3.540	1.586	0.486	-17.299	-.016

90MM M71



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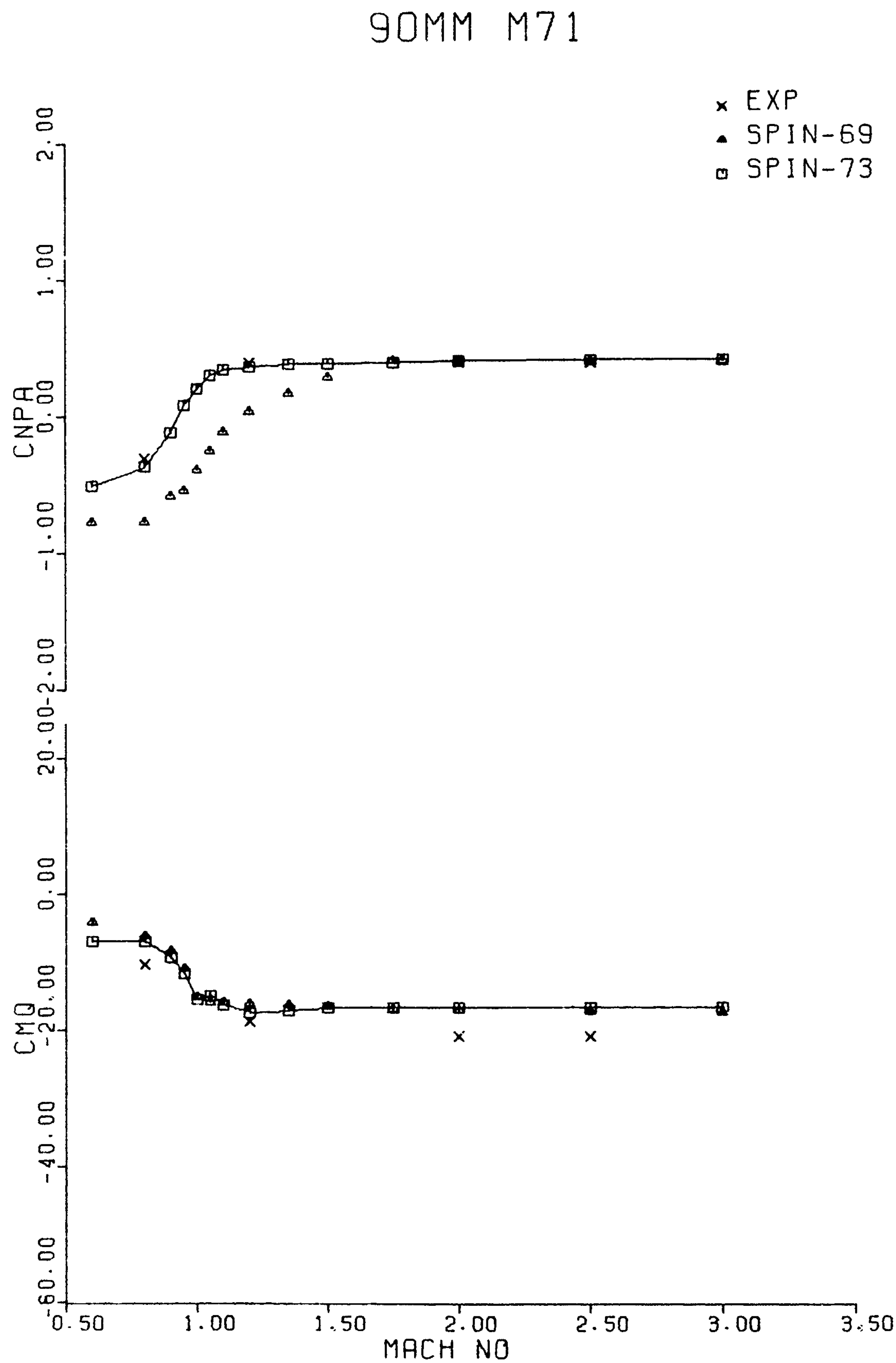
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1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

GE BURLINGTON VERMONT
M1

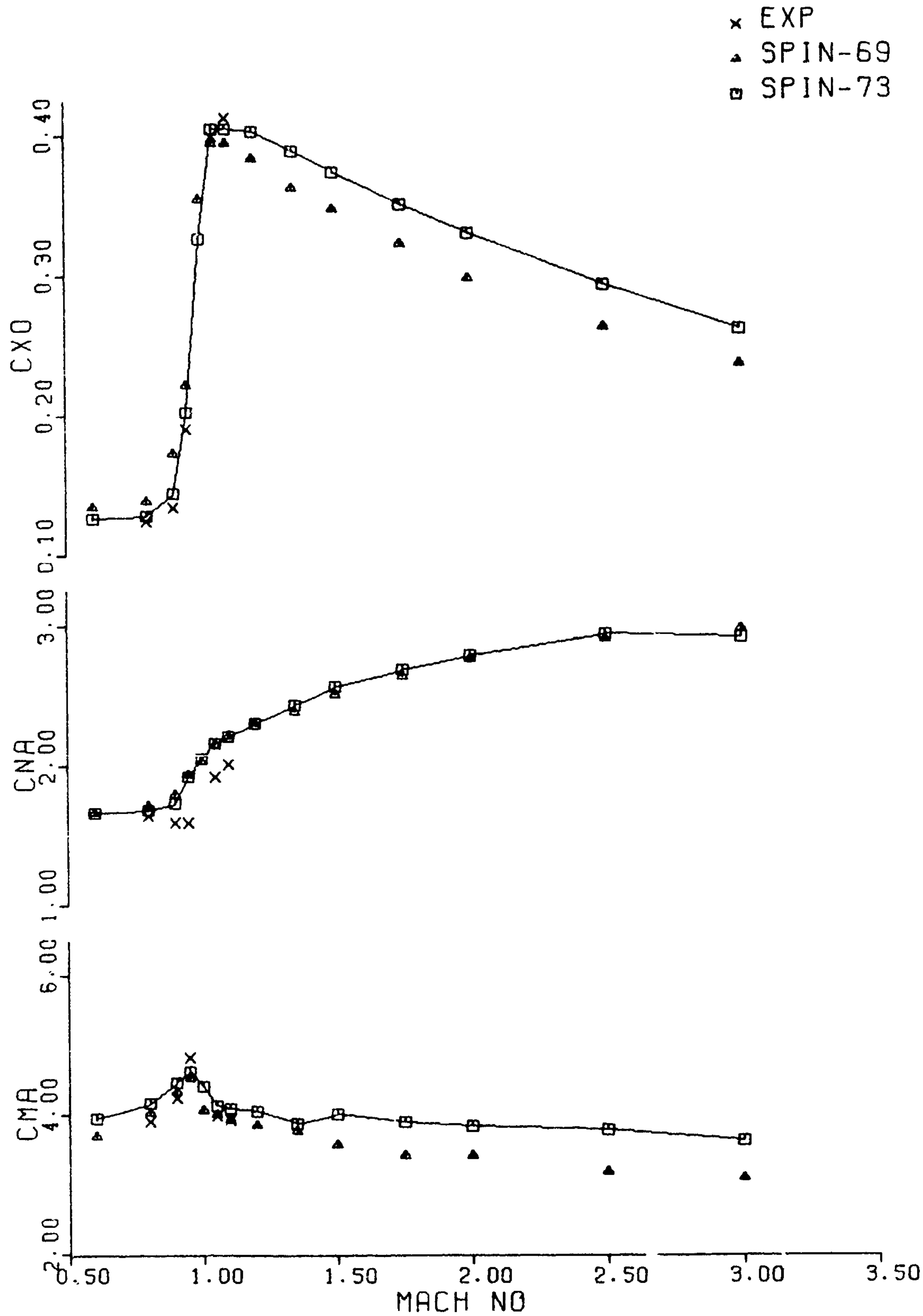
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
4.700	2.300	0.500	2.980	0.133	1.024	6.900	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	SPIN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GROOVE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
1.000	0.903	0.002	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CNFM1	CPFMN	CNPAM9	CMQ	CLP
0.010	0.127	2.551	1.673	3.919	0.625	-.802	-.491	91.494	-877.444	2.347	3.399	0.336	-7.495	-.031
0.600	0.127	2.551	1.673	3.940	0.612	-.802	-.491	91.494	-877.444	2.347	3.399	0.336	-7.495	-.031
0.800	0.129	3.373	1.693	4.170	0.519	-.802	-.341	83.119	-793.665	2.559	3.491	0.411	-7.495	-.030
0.900	0.145	3.612	1.745	4.473	0.417	-.896	-.089	60.683	-509.313	2.801	3.494	0.461	-9.740	-.025
0.950	0.233	4.221	1.927	4.615	0.675	-1.131	0.113	47.628	-434.778	3.080	3.462	0.546	-12.134	-.022
1.000	0.327	4.497	2.101	4.423	0.834	-1.037	0.233	32.483	-287.111	3.204	3.490	0.529	-15.998	-.020
1.050	0.405	5.034	2.147	4.131	1.474	-.943	0.333	19.420	-154.778	3.313	3.523	0.512	-15.478	-.020
1.100	0.435	5.56	2.272	4.303	1.138	-.896	0.374	13.483	-90.731	[illegible]	3.542	0.503	-16.758	-.020
1.200	0.403	6.107	2.307	4.069	1.216	-.802	0.396	9.610	-58.680	3.474	3.586	0.486	-18.002	-.020
1.350	0.389	5.527	2.437	3.889	1.386	-.802	0.411	7.939	-41.889	3.493	3.586	0.486	-17.697	-.020
1.500	0.374	4.941	2.573	4.012	1.421	-.802	0.419	7.103	-33.433	3.567	3.586	0.486	-17.299	-.020
1.750	0.351	4.374	2.690	3.801	1.533	-.802	0.426	6.268	-25.178	3.511	3.586	0.486	-17.299	-.019
2.000	0.330	3.824	2.790	3.832	1.607	-.802	0.434	5.432	-16.822	3.521	3.586	0.486	-17.299	-.019
2.500	0.293	3.099	2.932	3.759	1.690	-.802	0.441	4.597	-8.467	3.550	3.586	0.486	-17.299	-.018
3.000	0.261	2.567	2.903	3.505	1.742	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.017
4.000	0.223	2.105	2.803	3.562	1.709	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.017
5.000	0.201	1.644	2.703	3.574	1.676	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.016

105MM M1



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CMA
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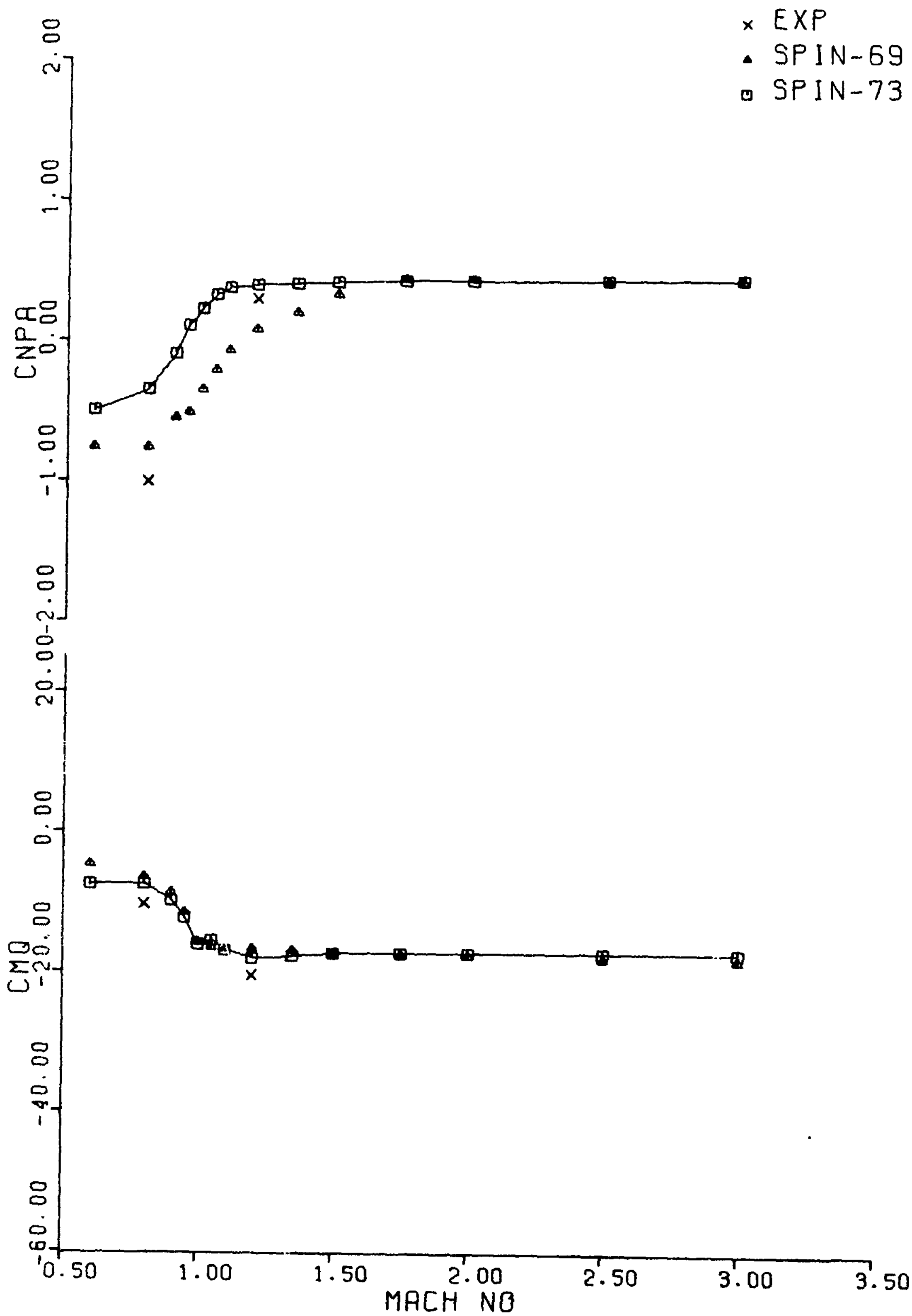
MACH NO

105MM M1



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CMQ
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1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

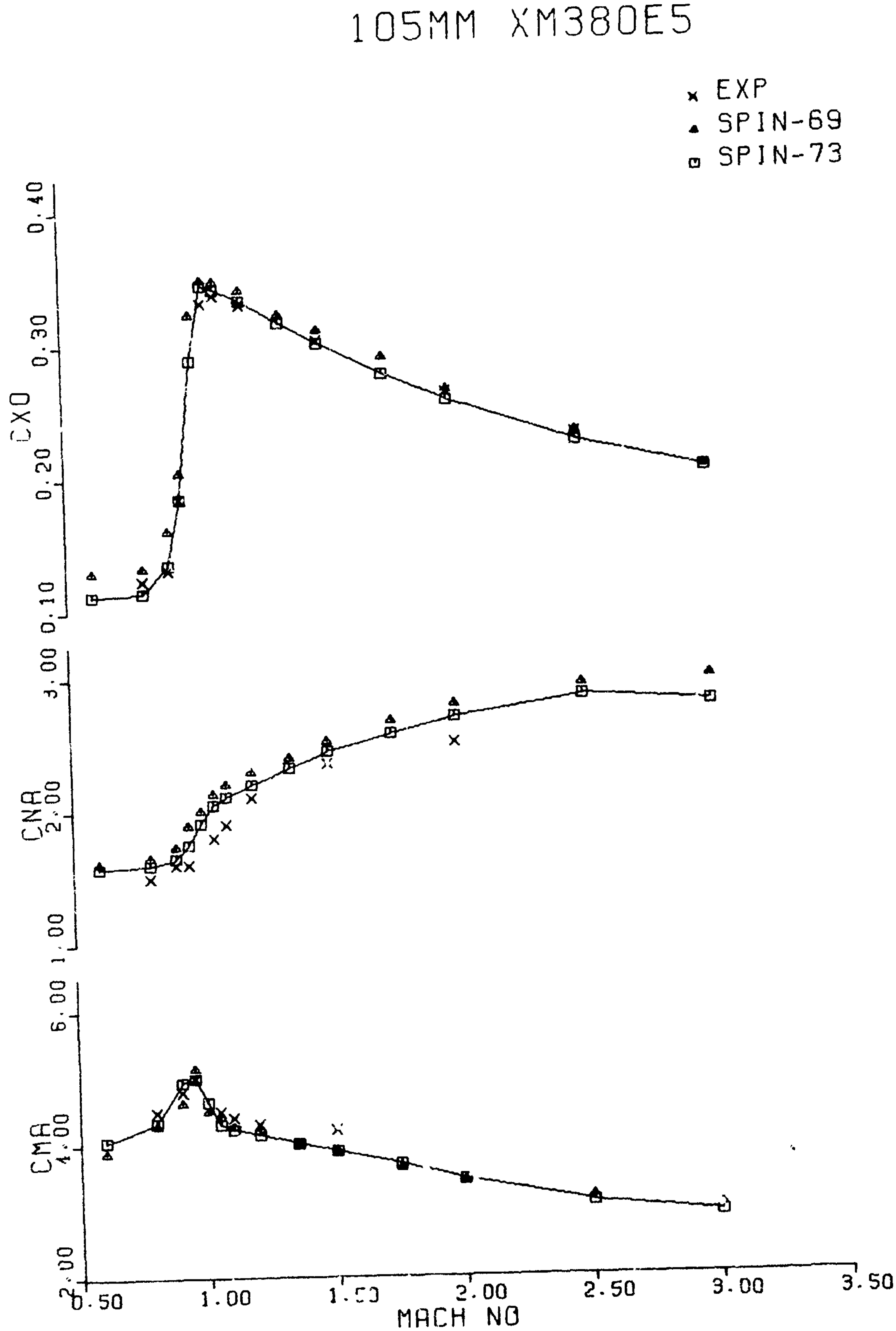
GE BURLINGTON VERMONT
XM38PE5

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
5.580	2.900	0.590	3.340	0.130	1.023	18.600	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CPFM1	CPFM5	CNPAM5	CMQ	CLP
0.010	0.113	2.494	1.579	4.045	0.778	-.952	-.296	108.703	-1049.533	3.029	4.061	0.686	-15.510	-.037
0.600	0.113	2.494	1.579	4.070	0.762	-.952	-.296	108.703	-1049.533	3.029	4.061	0.686	-15.510	-.037
0.800	0.115	2.95[illegible]	1.599	4.342	0.630	-.952	-.118	98.783	-950.333	3.217	4.155	0.775	-15.510	-.035
0.900	0.136	3.475	1.647	4.940	0.341	-1.063	0.207	72.123	-683.733	3.534	4.148	0.859	-17.799	-.030
0.950	0.185	3.954	1.753	4.998	0.488	-1.342	0.509	56.623	-524.733	3.719	4.102	1.023	-20.119	-.026
1.000	0.289	4.348	1.913	4.631	0.919	-1.231	0.626	38.643	-348.933	3.848	4.134	0.977	-23.869	-.024
1.050	0.345	4.844	2.050	4.301	1.242	-1.119	0.720	23.143	-193.933	3.984	4.173	0.937	-23.251	-.024
1.100	0.342	5.391	2.107	4.220	1.337	-1.063	0.759	16.323	-125.733	4.054	4.195	0.910	-24.968	-.024
1.200	0.333	5.913	2.198	4.134	1.459	-.952	0.757	11.487	-77.373	4.136	4.248	0.865	-26.770	-.024
1.350	0.316	5.354	2.316	3.996	1.615	-.952	0.775	9.503	-57.533	4.155	4.248	0.865	-27.069	-.023
1.500	0.303	4.786	2.443	3.872	1.755	-.952	0.784	8.511	-47.613	4.164	4.248	0.865	-28.028	-.023
1.750	0.276	4.221	2.567	3.686	1.904	-.952	0.793	7.519	-37.693	4.173	4.248	0.865	-28.028	-.023
2.000	0.256	3.652	2.695	3.431	2.067	-.952	0.802	6.527	-27.773	4.183	4.248	0.865	-28.028	-.022
2.500	0.224	2.992	2.845	3.075	2.259	-.952	0.811	5.535	-17.853	4.192	4.246	0.865	-28.028	-.021
3.000	0.203	2.521	2.781	2.891	2.301	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.020
4.000	0.165	2.086	2.681	2.870	2.270	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.020
5.000	0.143	1.651	2.581	2.843	2.239	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.019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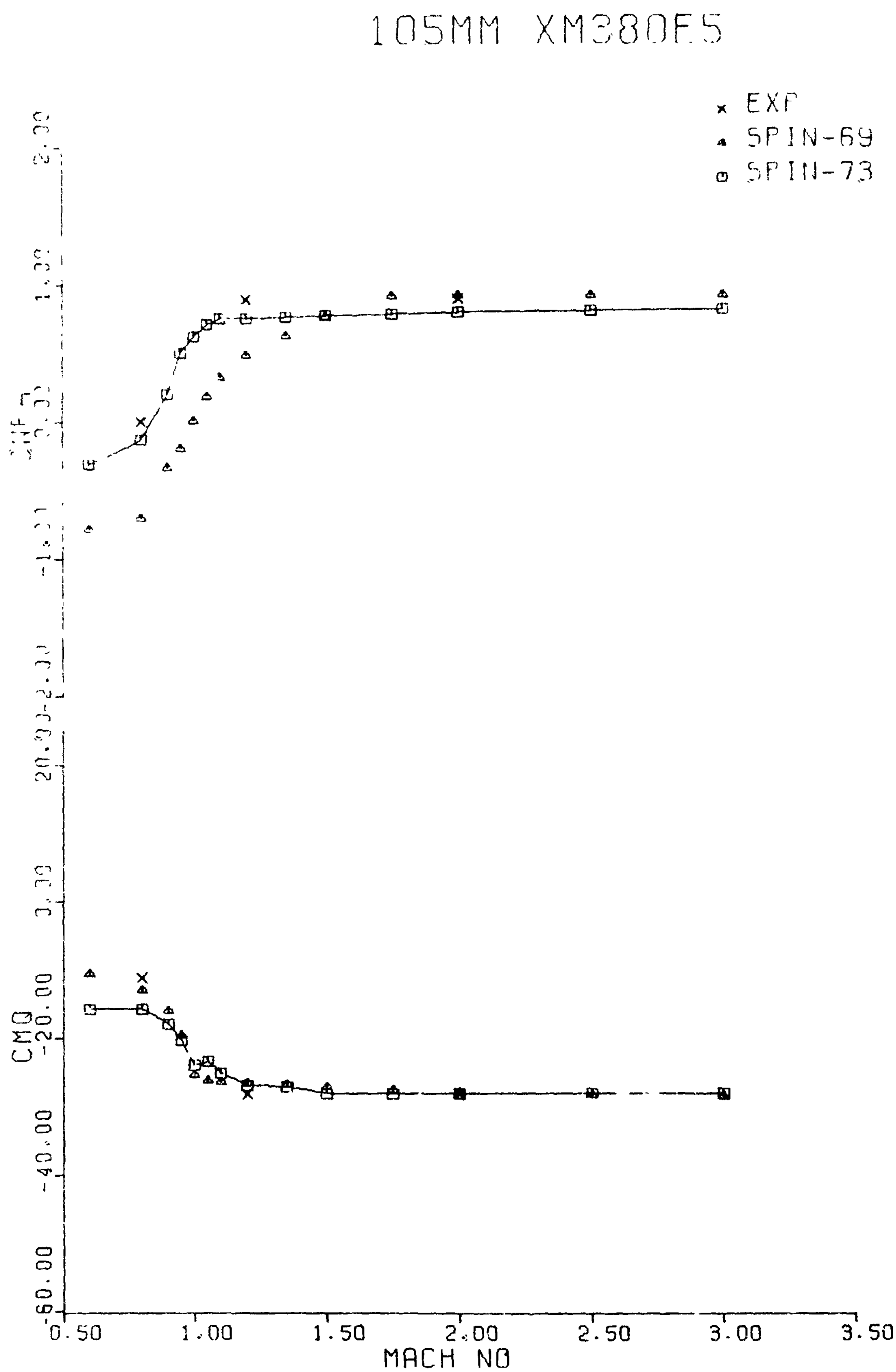
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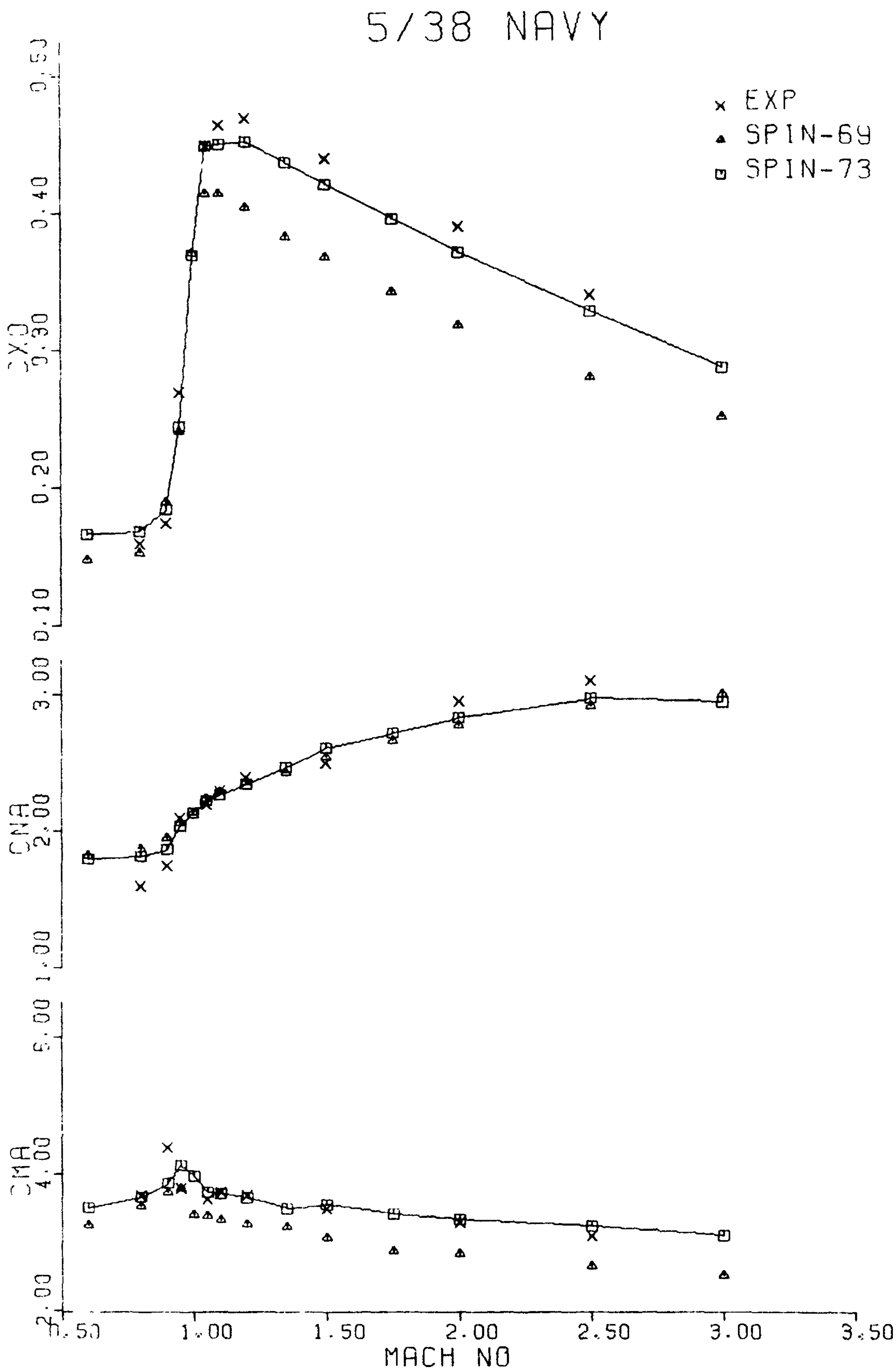
F R W NGTON VERMENT
5/3?

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
4.593	2.150	0.350	2.719	0.100	1.040	5.300	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
1.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CNPA3	CNPA5	CPF*1	CPF*5	CNPA*5	CMQ	CLP
0.010	0.167	2.64	1.799	3.494	0.769	-.769	-.369	89.343	-855.933	2.205	3.255	0.419	-9.419	-.030
0.600	0.167	2.64	1.799	3.514	0.757	-.769	-.389	89.343	-855.933	2.205	3.255	0.419	-9.419	-.030
0.800	0.169	3.167	1.819	3.690	0.681	-.769	-.242	81.183	-774.333	2.396	3.350	0.493	-9.419	-.029
0.900	0.185	3.634	1.874	3.843	0.638	-.861	0.028	59.253	-555.033	2.742	3.366	0.565	-11.750	-.024
0.950	0.245	4.105	2.045	4.135	0.604	-1.091	0.283	46.503	-427.533	2.970	3.357	0.706	-14.259	-.021
1.000	0.370	4.624	2.139	3.976	0.851	-.999	0.377	31.713	-279.633	3.087	3.377	0.666	-18.321	-.020
1.050	0.450	5.148	2.227	3.739	1.031	-.907	0.451	18.963	-152.133	3.208	3.400	0.626	-17.984	-.020
1.100	0.451	5.716	2.270	3.714	1.074	-.861	0.482	13.353	-96.033	3.270	3.414	0.606	-19.352	-.020
1.200	0.453	6.277	2.350	3.653	1.155	-.769	0.478	9.375	-56.253	3.331	3.446	0.566	-20.595	-.019
1.350	0.437	5.691	2.471	3.494	1.296	-.769	0.493	7.743	-39.933	3.350	3.446	0.566	-20.122	-.019
1.500	0.421	5.091	2.606	3.569	1.341	-.769	0.500	6.927	-31.773	3.360	3.446	0.566	-18.992	-.019
1.750	0.396	4.518	2.714	3.408	1.454	-.769	0.507	6.111	-23.613	3.369	3.446	0.566	-18.992	-.019
2.000	0.371	3.940	2.827	3.331	1.532	-.769	0.515	5.295	-15.453	3.379	3.446	0.566	-18.992	-.018
2.500	0.328	3.225	2.953	3.206	1.624	-.769	0.522	4.479	-7.293	3.388	3.446	0.566	-18.992	-.017
3.000	0.287	2.667	2.929	3.071	1.661	-.769	0.529	3.663	0.867	3.398	3.446	0.566	-18.992	-.017
4.000	0.249	2.191	2.829	3.060	1.626	-.769	0.529	3.663	0.867	3.398	3.446	0.566	-18.992	-.016
5.000	0.227	1.714	2.729	3.043	1.595	-.769	0.529	3.663	0.867	3.398	3.446	0.566	-18.992	-.016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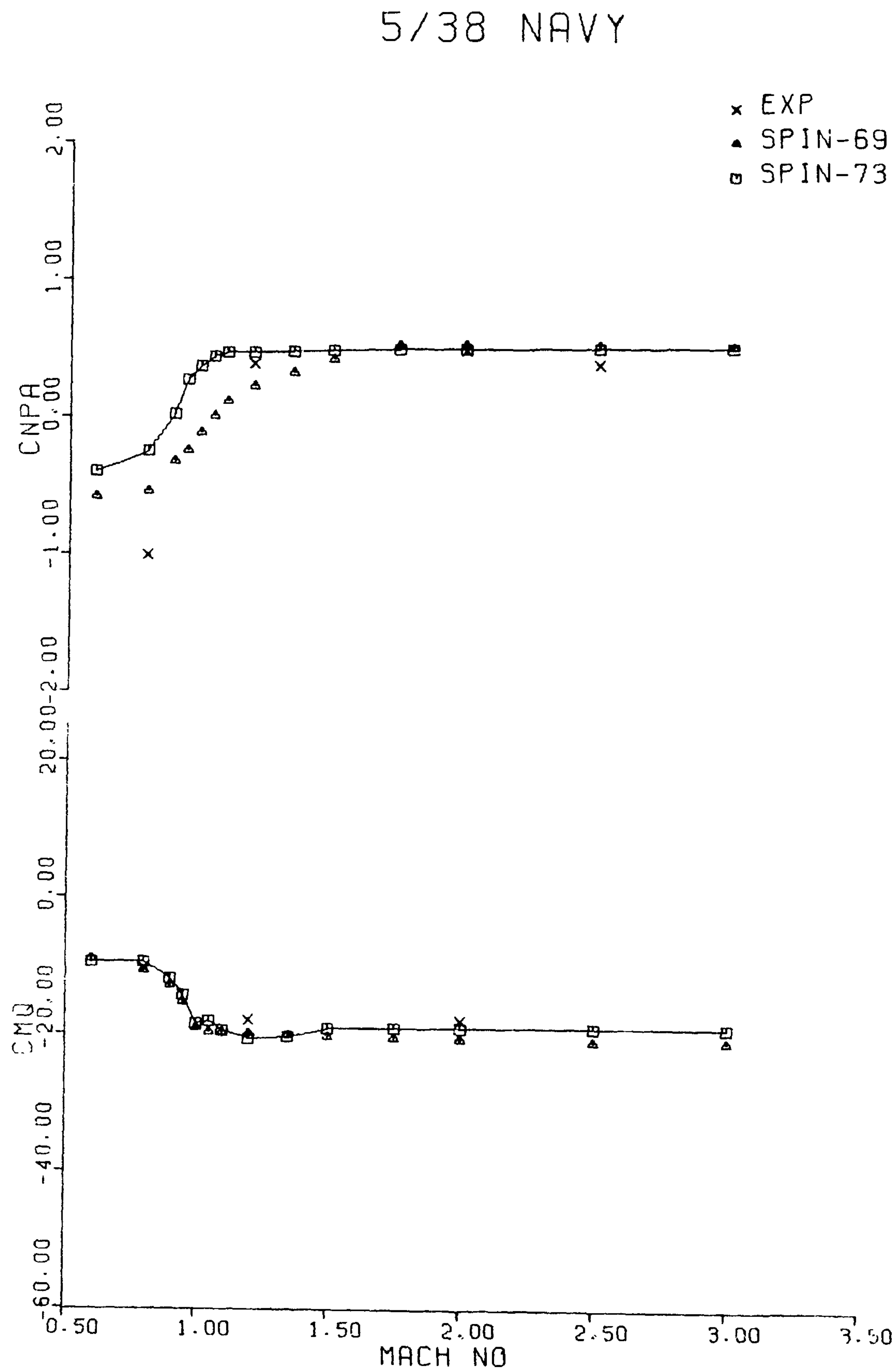
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MACH NO

[illegible] 6/94

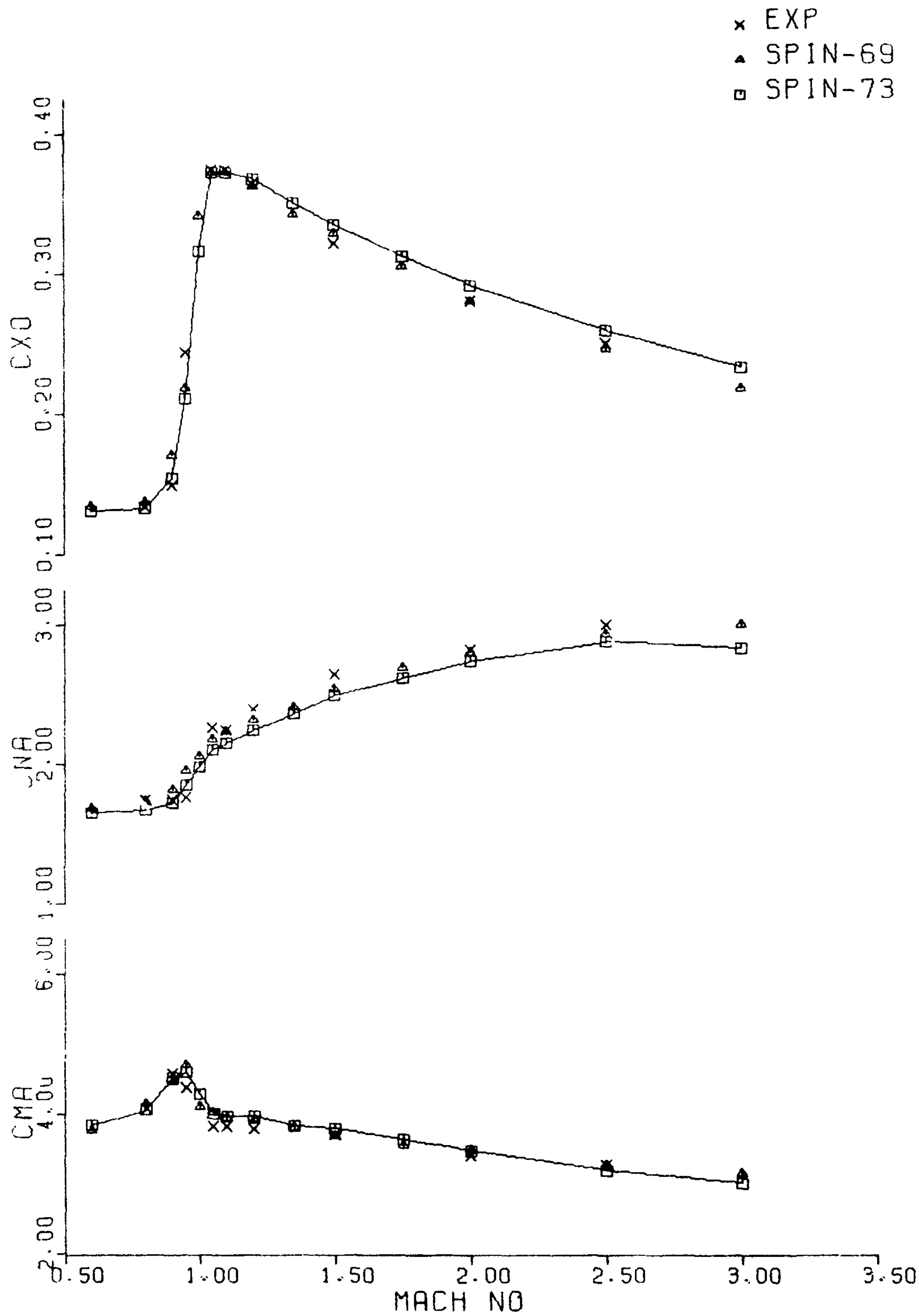
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
[illegible]	[illegible]	[illegible]	[illegible]	0.110	[illegible]	13.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT [illegible]	DES TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CYPA	CNPA	CNPA3	[illegible]	CXF[illegible]	CPF[illegible]	CNPA5	CMQ	CLP
[illegible]	0.132	2.911	1.662	3.413	[illegible]	-.894	-.407	102.448	[illegible]	2.760	3.798	0.524	-11.942	-.035
[illegible]	0.132	2.911	1.662	3.446	[illegible]	-.894	-.403	102.448	[illegible]	2.760	3.798	0.524	-11.942	-.035
[illegible]	0.134	[illegible]	1.682	4.186	1.778	-.894	-.211	93.094	-893.464	2.949	3.891	0.608	-11.942	-.033
[illegible]	0.155	4.526	1.726	4.546	1.627	-.990	0.084	67.963	-642.1[illegible]	3.274	3.896	0.680	-14.283	-.028
[illegible]	0.212	4.957	1.859	4.411	1.734	-1.262	0.330	53.352	-494.0[illegible]	3.471	3.855	0.814	-18.674	-.024
1.000	0.317	4.415	1.995	4.109	1.656	-1.157	-.440	36.403	-326.5[illegible]	3.597	3.884	0.779	-20.537	-.023
1.050	0.373	4.495	2.112	4.929	1.501	-1.051	0.544	21.792	-180.47[illegible]	3.728	3.918	0.744	-20.015	-.023
1.100	0.373	4.415	2.165	3.992	1.376	-.900	0.565	15.303	-118.13[illegible]	3.796	3.93[illegible]	0.727	-21.620	-.023
1.200	0.164	5.977	2.252	3.975	1.409	-.894	0.591	10.809	-76.[illegible]47	3.872	3.985	0.692	-23.268	-.022
1.350	0.151	5.439	2.372	3.843	1.490	-.894	0.608	8.936	-51.844	3.891	3.989	0.692	-23.479	-.022
1.500	0.139	4.831	2.502	3.804	1.690	-.594	0.617	7.999	-47.495	3.900	3.985	0.692	-24.078	-.022
1.750	0.312	4.266	2.619	3.690	1.817	-.894	0.625	7.064	-33.147	3.909	3.985	0.692	-24.078	-.021
2.000	0.291	3.707	2.737	3.471	1.849	-.894	0.633	6.129	-23.791	3.919	3.985	0.692	-24.078	-.021
2.500	0.259	3.114	2.692	3.247	2.080	-.894	0.642	5.194	-14.440	3.928	3.985	0.692	-24.078	-.020
3.000	0.233	2.524	2.843	3.089	2.124	-.894	0.650	4.259	-5.089	3.938	3.985	0.692	-24.078	-.019
4.000	0.195	2.309	2.743	3.042	2.694	-.894	0.650	4.259	-5.089	3.938	3.985	0.692	-24.078	-.019
5.000	0.173	1.637	2.643	3.010	2.864	-.894	0.650	4.259	-5.089	3.938	3.985	0.692	-24.078	-.018

5/54 NAVY



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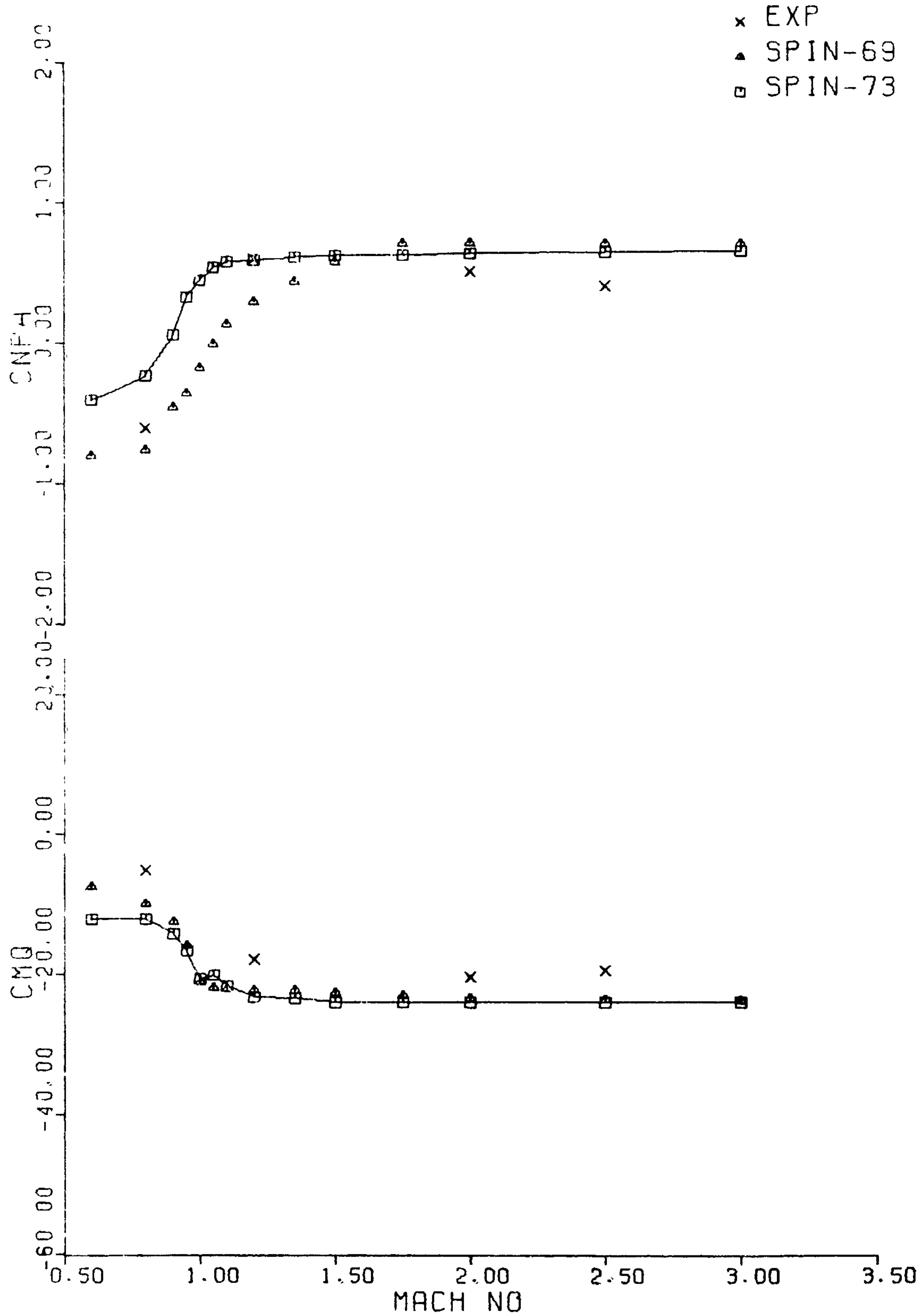
5/54 NAVY



SP WEATHINGTON SEGMENT
#101

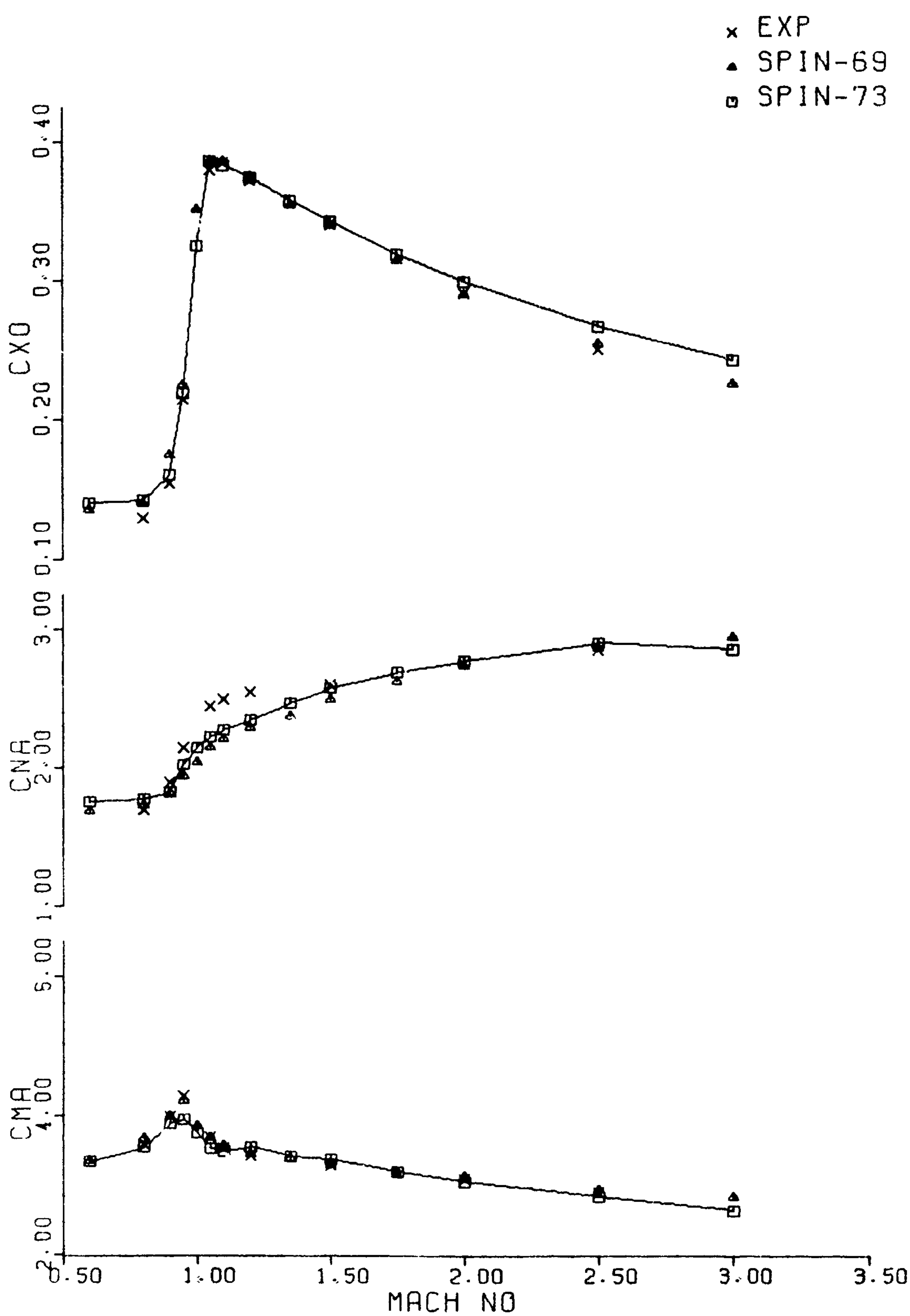
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
4.910	2.490	0.490	2.960	0.098	1.020	10.750	0.000

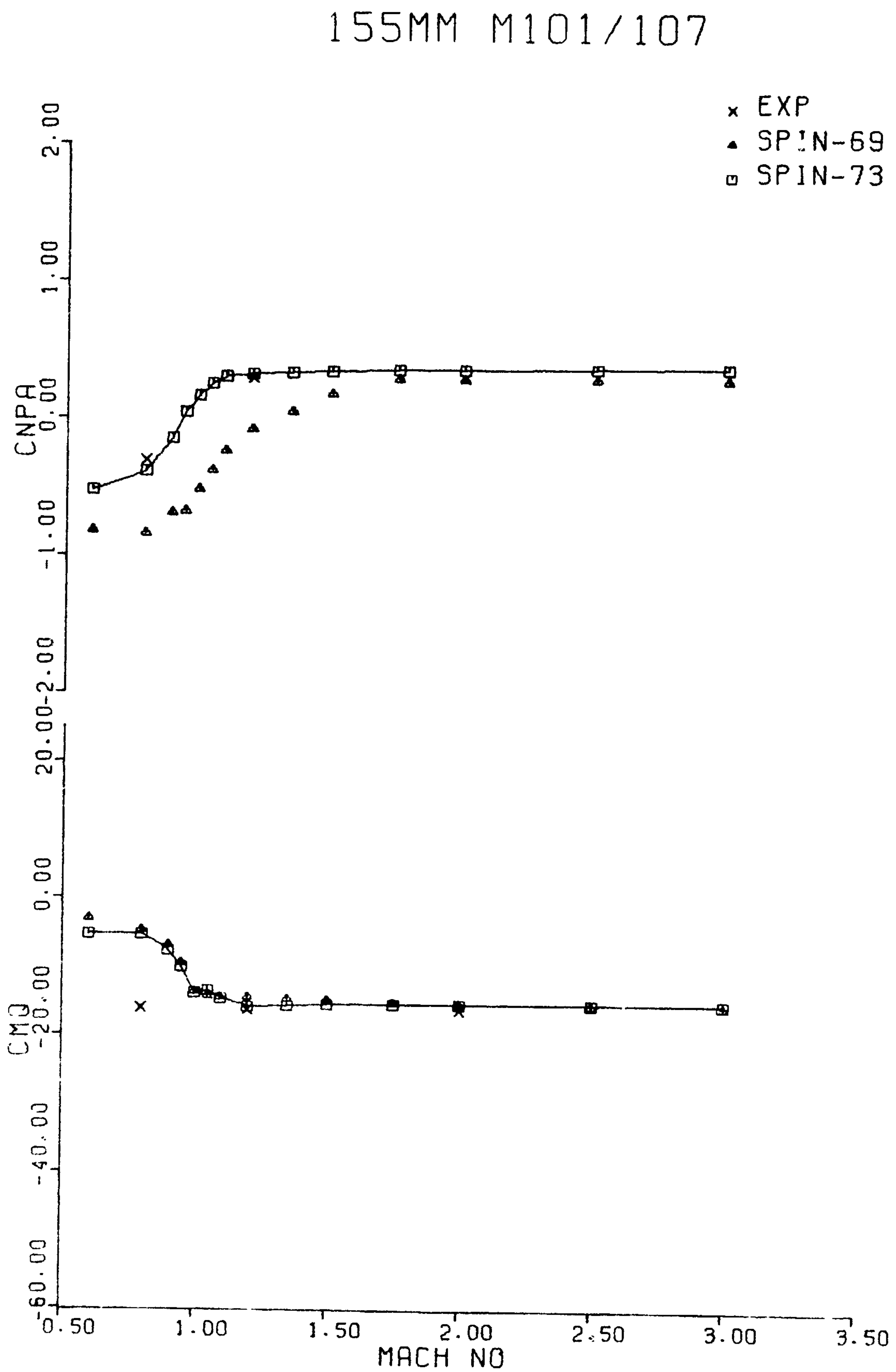
DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.1[illegible]	0.000	0.000	0.030	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPN	CYPA	CNPA	CMPA3	CMPA5	CPFM1	CPFM5	CMPAM5	CMQ	CLP
0.010	0.141	2.307	1.763	3.316	1.868	-.767	-.524	87.779	-840.249	2.277	3.312	0.270	-5.225	-.030
0.600	0.141	2.362	1.743	3.348	1.894	-.767	-.524	87.779	-840.249	2.277	3.312	0.270	-5.225	-.030
0.800	0.143	2.859	1.783	3.592	0.968	-.767	-.370	70.741	-786.[illegible]	2.445	3.404	0.342	-5.225	-.028
0.900	0.161	3.371	1.831	3.850	0.831	-.857	-.130	50.213	-544.833	2.797	3.413	0.388	-7.533	-.024
0.950	0.219	3.729	2.039	3.967	1.013	-1.082	0.058	49.686	-419.156	3.004	3.390	0.445	-9.961	-.021
1.000	0.425	4.177	2.191	3.770	1.208	-.992	0.146	31.153	-274.635	3.178	3.414	0.491	-13.892	-.020
1.050	0.486	4.661	2.232	3.547	1.171	-.902	0.265	18.476	-146.756	3.294	3.444	0.436	-13.436	-.019
1.100	0.483	5.182	2.279	3.588	1.421	-.857	0.307	13.113	-93.833	3.318	3.461	0.429	-14.461	-.019
1.200	0.474	5.684	2.390	3.596	1.447	-.767	0.328	9.205	-54.947	3.388	3.491	0.414	-15.845	-.019
1.350	0.457	5.113	2.444	3.494	1.471	-.767	0.342	7.601	-38.911	3.406	3.501	0.414	-15.601	-.019
1.500	0.442	4.542	2.501	3.372	1.494	-.767	0.349	6.709	-30.403	3.416	3.501	0.414	-15.343	-.019
1.750	0.318	3.979	2.690	3.196	1.772	-.767	0.357	5.998	-22.478	3.425	3.501	0.414	-15.343	-.018
2.000	0.298	3.443	2.770	3.070	1.859	-.767	0.354	5.196	-14.458	3.439	3.501	0.414	-15.343	-.018
2.500	0.266	2.784	2.898	2.931	1.981	-.767	0.371	4.394	-6.440	3.444	3.501	0.414	-15.343	-.017
3.000	0.242	2.312	2.849	2.840	2.038	-.767	0.378	3.592	1.578	3.454	3.501	0.414	-15.343	-.016
4.000	0.204	1.893	2.749	2.618	2.008	-.767	0.378	3.592	1.578	3.454	3.501	0.414	-15.343	-.016
5.000	0.182	1.469	2.649	2.491	1.978	-.767	0.378	3.592	1.578	3.454	3.501	0.414	-15.343	-.016

155MM M101/107

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3.50

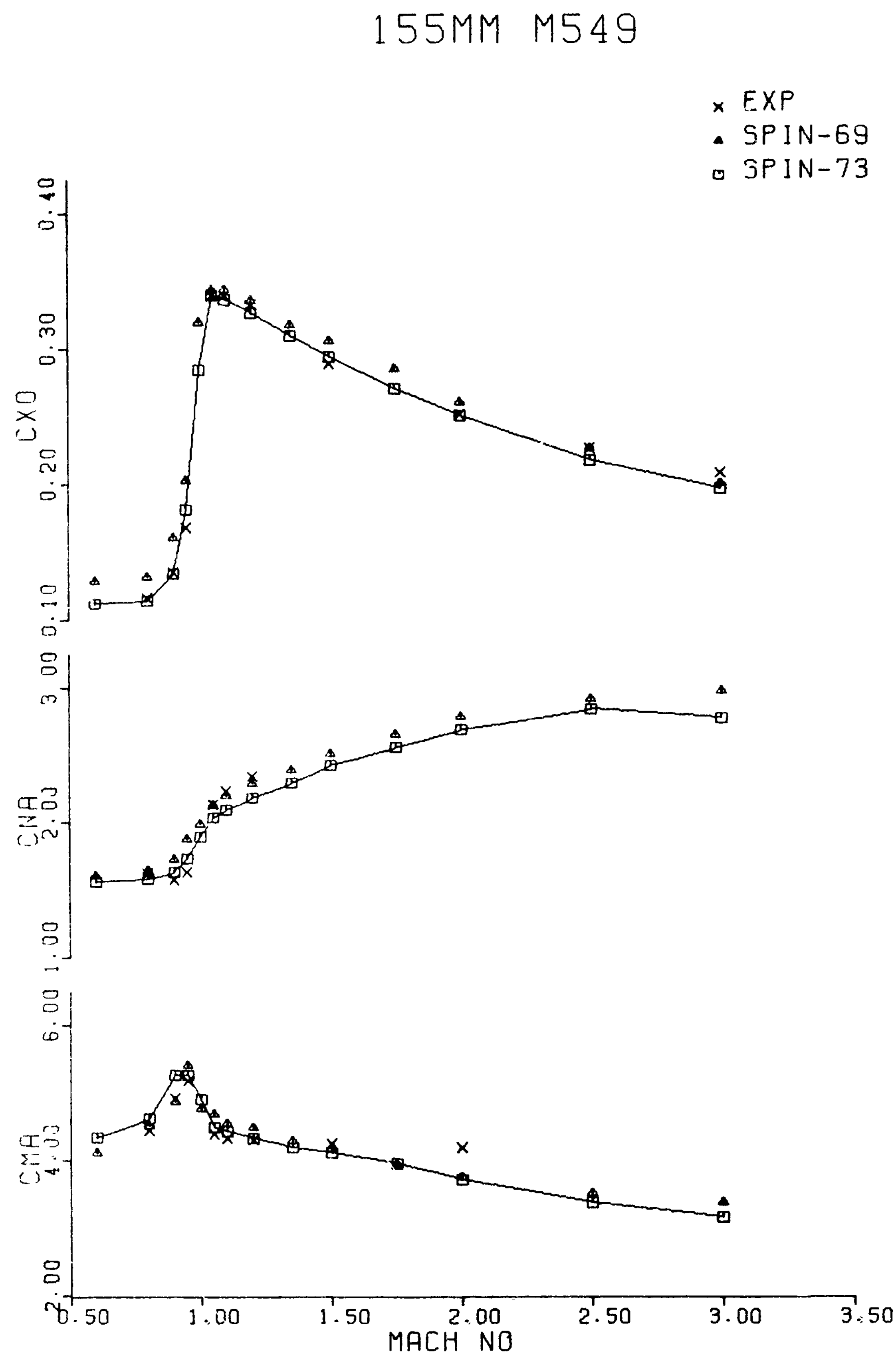
[illegible]
[illegible] 549

TOTAL LENGTH	NOSE LENGTH	[illegible]	CG (FROM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
5.456	2.90[illegible]	0.590	3.[illegible]20	0.090	[illegible]	10.900	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	[illegible]	0.60[illegible]	[illegible]	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CYMA	CNPA	CNPA3	[illegible]	CPF=1	CPF=5	CNPA=5	CMQ	CLP
0.010	.113	2.5[illegible]4	1.5[illegible]	4.340	[illegible]	-.963	[illegible]	110.072	-1063.222	3.049	4.121	0.579	-12.772	-.037
0.600	.113	2.5[illegible]4	1.5[illegible]9	4.378	[illegible]	-.963	[illegible]	110.072	-1063.222	3.049	4.121	0.579	-12.772	-.037
0.800	0.115	2.983	1.590	4.4[illegible]7	[illegible]	-.963	[illegible]	100.028	-962.776	3.276	4.215	0.669	-12.772	-.035
0.900	0.135	3.93[illegible]	1.649	5.287	[illegible]	-1.076	[illegible]	73.033	-692.[illegible]	3.594	4.209	0.741	-15.149	-.030
0.950	0.182	3.97[illegible]	1.744	5.281	[illegible]	-1.358	0.353	57.119	-535.[illegible]	3.780	4.162	0.873	-17.482	-.026
1.000	0.285	4.465	1.935	4.930	3.937	-1.245	0.484	39.133	-353.[illegible]	3.960	4.195	0.840	-21.247	-.025
1.050	0.340	4.864	2.340	4.5[illegible]6	[illegible]	-1.132	0.591	23.419	-196.[illegible]	4.044	4.234	0.808	-20.652	-.024
1.100	0.337	5.432	2.097	4.432	1.406	-1.076	0.649	16.533	-127.833	4.114	4.256	0.792	-22.437	-.024
1.200	0.327	5.924	2.188	4.349	1.437	-.963	0.651	11.637	-76.867	4.196	4.309	0.760	-24.372	-.024
1.350	0.310	5.375	2.305	4.297	1.495	-.963	0.669	9.628	-58.778	4.215	4.309	0.760	-25.130	-.024
1.500	0.294	4.811	2.430	4.192	1.828	-.963	0.678	8.623	-48.733	4.224	4.309	0.760	-26.922	-.024
1.750	0.270	4.242	2.557	3.957	1.973	-.963	0.687	7.619	-38.689	4.234	4.309	0.760	-26.922	-.023
2.000	0.250	3.672	2.686	3.743	2.138	-.963	0.696	6.614	-28.644	4.243	4.309	0.760	-26.922	-.023
2.500	0.217	3.306	2.837	3.379	2.329	-.963	0.705	5.610	-18.600	4.253	4.309	0.760	-26.927	-.022
3.000	0.196	2.536	2.771	3.170	2.374	-.963	0.714	4.606	-8.556	4.262	4.309	0.760	-25.922	-.021
4.000	0.158	2.101	2.671	3.139	2.345	-.963	0.714	4.606	-8.556	4.262	4.309	0.760	-26.927	-.020
5.000	0.136	1.665	2.571	3.101	2.314	-.963	0.714	4.606	-8.556	4.262	4.309	0.760	-26.922	-.019



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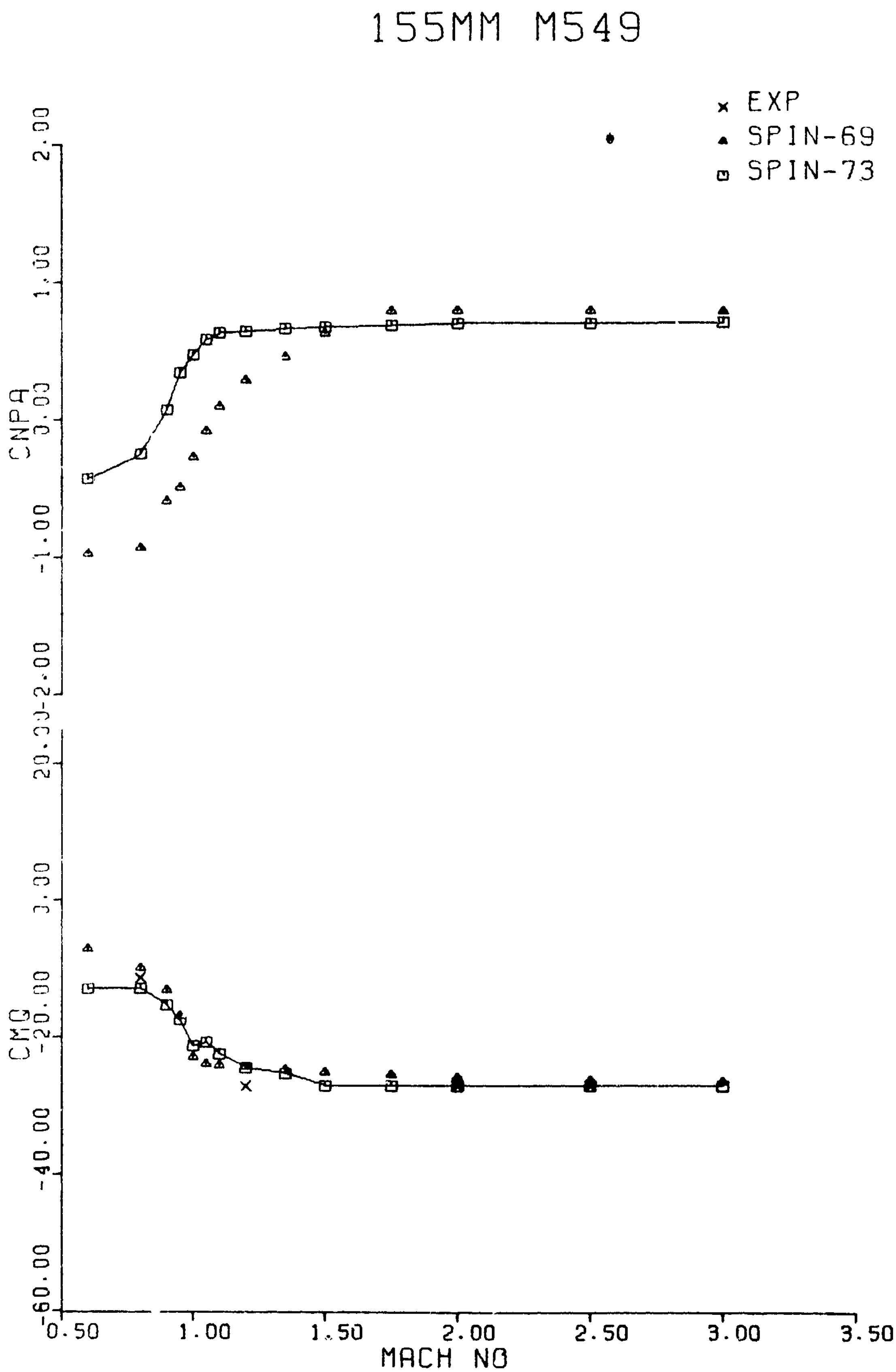
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GE BURLINGTON VERMONT
175MM M437

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
5.510	2.910	1.000	3.500	0.079	1.050	25.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
6.885	954.000	10850.000	148.000	20.000	20.000	6.885	59.000	0.00238

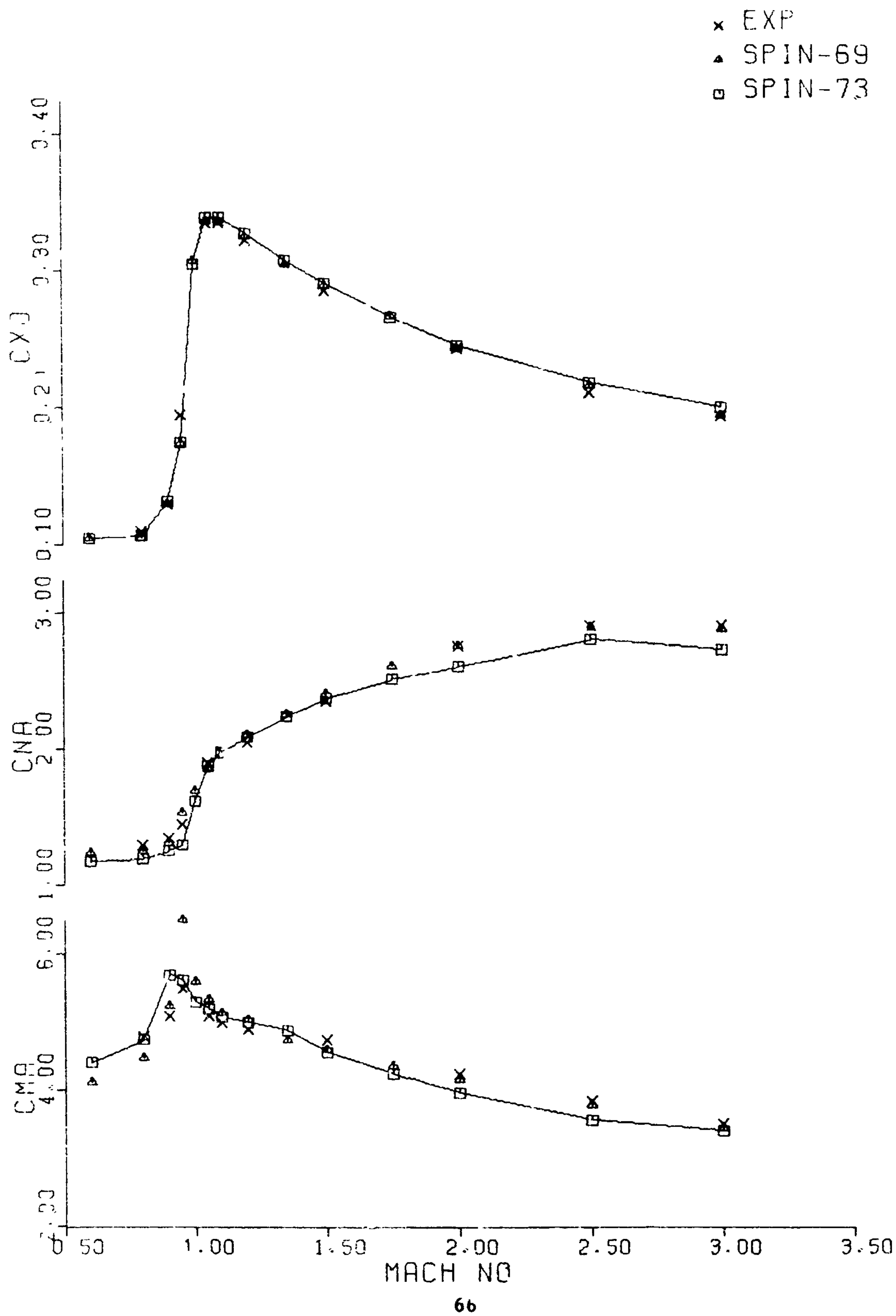
AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CMQ	CYPA	CNPA	CNPA3	CNPA5	CMPM1	CMPM5	CNPAM5	CMG	C.P.
0.010	0.135	2.329	1.178	4.364	-.222	-.982	-.319	107.334	-1035.844	3.155	4.143	0.631	-12.101	-.036
0.600	0.135	2.329	1.178	4.411	-.245	-.982	-.339	107.334	-1035.844	3.155	4.143	0.631	-12.101	-.036
0.800	0.137	2.603	1.198	4.770	-.485	-.982	-.162	97.679	-937.889	3.335	4.235	0.719	-12.101	-.035
0.900	0.132	3.331	1.263	5.768	-1.019	-1.092	0.111	71.213	-674.633	3.602	4.192	0.756	-13.870	-.029
0.950	0.175	3.893	1.298	5.618	-.827	-1.367	0.294	55.908	-521.678	3.715	4.066	0.801	-15.792	-.025
1.000	0.305	4.163	1.624	5.310	0.230	-1.257	0.456	38.153	-344.033	3.862	4.139	0.803	-18.937	-.024
1.050	0.339	4.507	1.879	5.123	0.737	-1.147	0.595	22.848	-190.976	4.019	4.201	0.805	-17.717	-.024
1.100	0.339	[illegible]	1.983	5.020	0.933	-1.092	0.657	16.113	-123.633	4.101	4.236	0.805	-18.929	-.024
1.200	0.327	5.503	2.089	4.971	1.110	-.982	0.702	11.338	-75.880	4.215	4.322	0.807	-20.259	-.023
1.350	0.307	4.944	2.245	4.887	1.323	-.982	0.719	9.379	-56.289	4.233	4.322	0.807	-19.546	-.023
1.500	0.290	[illegible]	2.369	4.566	1.573	-.982	0.728	8.399	-46.493	4.242	4.322	0.807	-19.826	-.023
1.750	0.265	3.882	2.506	4.231	1.812	-.982	0.737	7.420	-36.696	4.251	4.322	0.807	-19.826	-.022
2.000	0.244	3.388	2.601	3.966	1.975	-.982	0.746	6.440	-26.902	4.260	4.322	0.807	-19.826	-.022
2.500	0.217	2.732	2.799	3.568	2.225	-.982	0.754	5.461	-17.107	4.269	4.322	0.807	-19.826	-.021
3.000	0.199	2.279	2.723	3.400	2.251	-.982	0.763	4.481	-7.311	4.278	4.322	0.807	-19.826	-.020
4.000	0.164	1.881	2.623	3.371	2.215	-.982	0.763	4.481	-7.311	4.278	4.322	0.807	-19.826	-.019
5.000	0.146	1.481	2.523	3.335	2.178	-.982	0.763	4.481	-7.311	4.278	4.322	0.807	-19.826	-.019

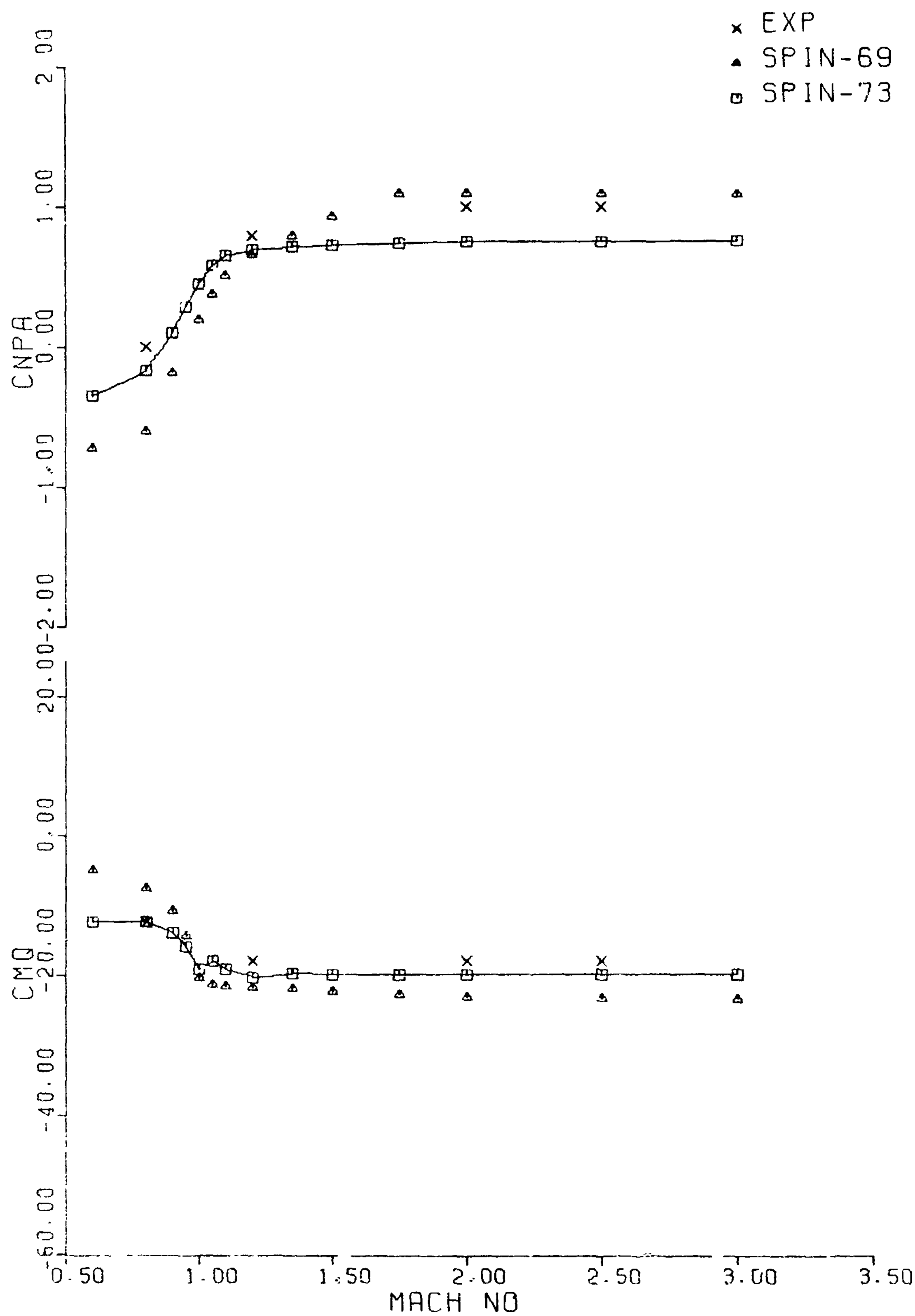
STABILITY ANALYSIS

MACH	GYRO	SDAR	RECIP	SDAR*5	RECIP*5	SPIN	W1	W2	L1	L2	L1*5	L2*5	DELT	DISP
0.010	1.760	-.371	-6.798	1.399	1.189	6.1	0.45	0.09	-.000435	0.000096	-.000073	-.000267	0.7049	0.300
0.600	1.749	-.371	-6.798	1.399	1.189	366.9	26.69	5.57	-.000437	0.000097	-.000073	-.000267	0.0116	0.297
0.800	1.618	0.202	2.748	1.532	1.395	469.2	34.70	8.22	-.000342	0.000041	-.000032	-.000310	0.0790	0.263
0.900	1.352	0.559	1.241	1.420	1.214	550.3	36.53	11.85	-.000349	-.000035	-.000039	-.000345	0.0086	0.188
0.950	1.373	0.718	1.086	1.326	1.119	580.9	38.85	12.22	-.000319	-.000108	-.000081	-.000347	0.0081	0.196
1.000	1.453	0.814	1.036	1.162	1.027	611.5	41.89	11.87	-.000327	-.000190	-.000175	-.000343	0.0075	0.258
1.050	1.486	1.039	1.001	1.253	1.066	642.1	44.37	12.09	-.000223	-.000285	-.000133	-.000375	0.0071	0.316
1.100	1.516	1.057	1.003	1.200	1.042	672.6	46.82	12.32	-.000231	-.000310	-.000166	-.000373	0.0067	0.351
1.200	1.546	1.056	1.003	1.150	1.023	733.8	51.43	13.09	-.000249	-.000328	-.000205	-.000371	0.0061	0.391
1.350	1.579	1.121	1.015	1.201	1.042	825.5	58.26	14.32	-.000219	-.000353	-.000183	-.000389	0.0054	0.447
1.500	1.690	1.132	1.018	1.201	1.042	917.2	66.09	14.56	-.000224	-.000362	-.000194	-.000392	0.0048	0.542
1.750	1.823	1.154	1.025	1.216	1.049	1070.1	78.66	15.43	-.000222	-.000373	-.000197	-.000399	0.0040	0.663
2.000	1.945	1.174	1.031	1.226	1.054	1223.0	91.25	16.28	-.000221	-.000381	-.000199	-.000403	0.0034	0.772
2.500	2.162	1.202	1.042	1.245	1.064	1528.7	116.48	17.93	-.000219	-.000396	-.000202	-.000413	0.0027	0.989
3.000	2.269	1.203	1.043	1.240	1.061	1834.4	140.96	20.33	-.000219	-.000391	-.000204	-.000405	0.0022	1.035
4.000	2.289	1.197	1.040	1.234	1.058	2445.9	188.22	26.84	-.000220	-.000383	-.000206	-.000397	0.0017	1.020
5.000	2.313	1.189	1.037	1.227	1.054	3057.4	235.69	33.14	-.000222	-.000375	-.000207	-.000389	0.0013	1.001

175MM M437



175MM M437



× EXP
▲ SPIN-69
□ SPIN-73
CNPA
CMQ
2.00
1.00
0.00
-1.00
-2.00
20.00
0.00
-20.00
-40.00
-60.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

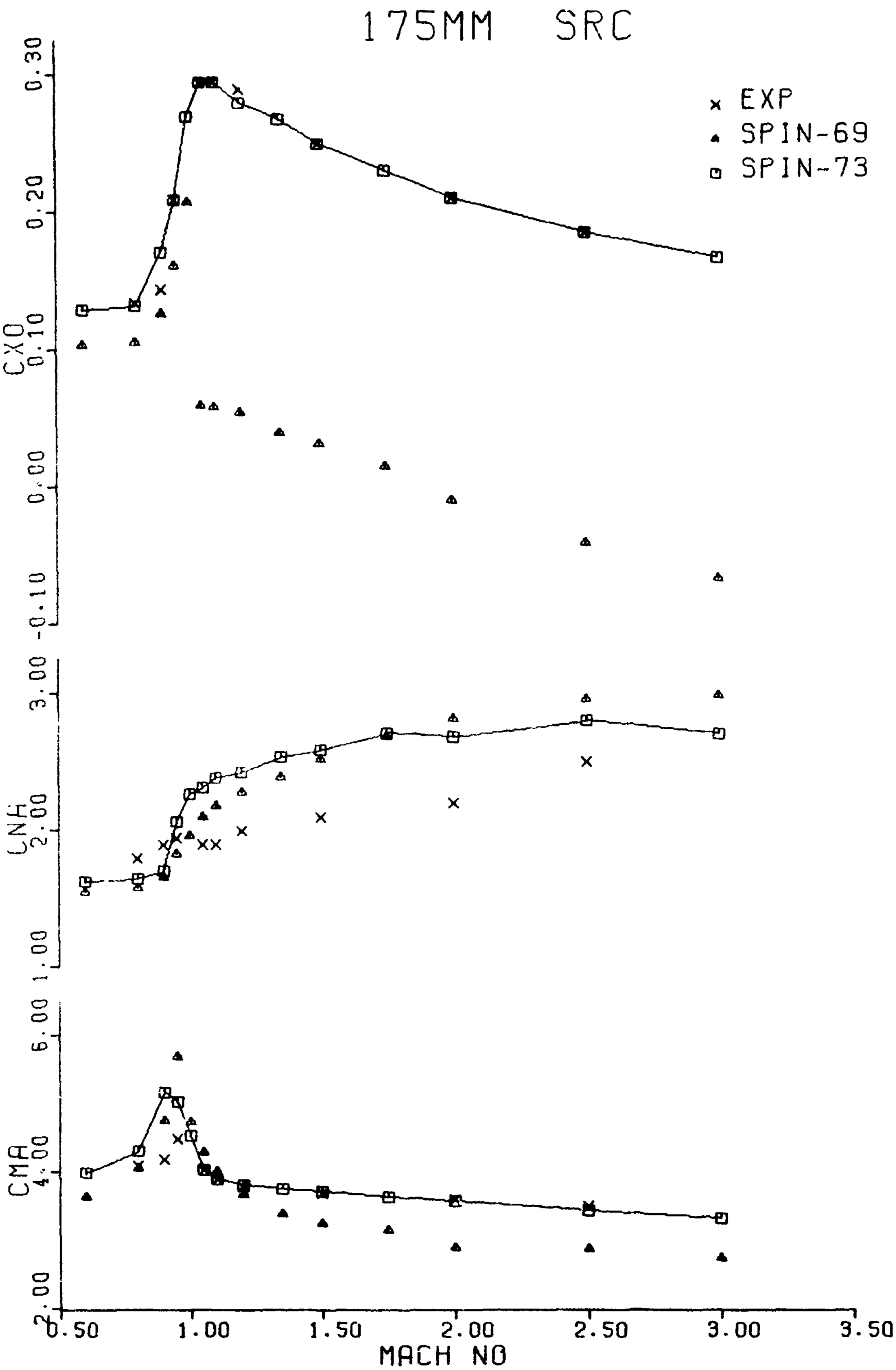
[illegible]

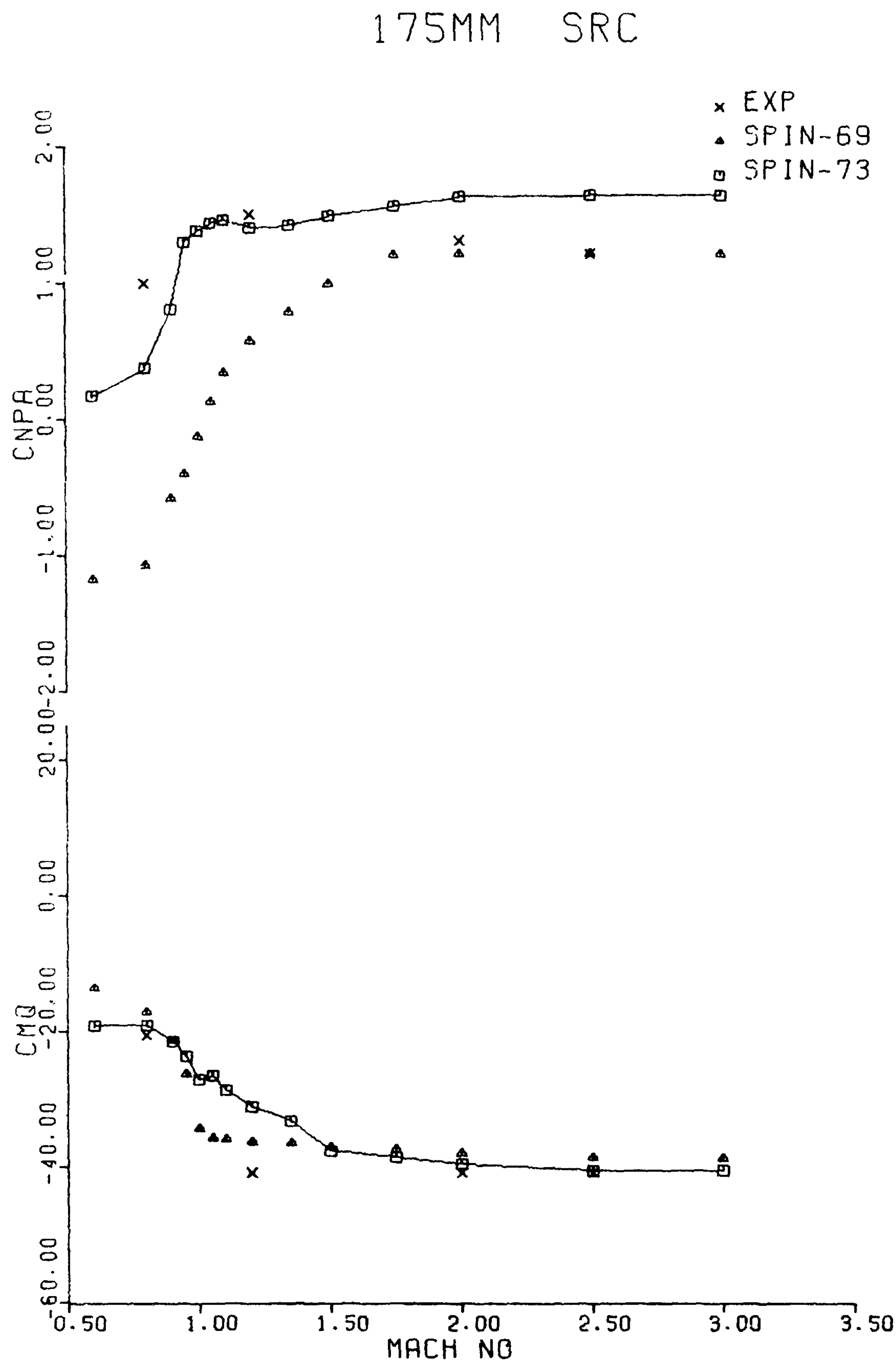
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
[illegible]	[illegible]	[illegible]	4.030	0.090	1.000	120.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	[illegible]	[illegible]	[illegible]	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	[illegible]	CYPA	CNPA	CNPA3	CNPA5	CPF=1	CPF=5	CNPA=5	CMQ	CLP
[illegible]	[illegible]	[illegible]	[illegible]	3.973	[illegible]	-1.110	0.176	126.694	-1229.444	4.189	5.220	1.320	-18.975	-.043
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.676	-1.110	0.176	126.694	-1229.444	4.189	5.220	1.320	-18.975	-.043
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.714	-1.110	0.384	[illegible]	[illegible]	4.376	[illegible]	1.424	-16.975	-.041
[illegible]	[illegible]	2.785	[illegible]	5.172	[illegible]	-1.240	[illegible]	84.083	[illegible]	4.687	5.300	1.575	-21.356	-.034
0.950	0.207	2.934	2.067	[illegible]	1.496	-1.565	1.299	66.028	-622.778	4.860	5.242	1.897	-23.537	-.030
[illegible]	0.269	3.275	2.271	4.549	2.027	-1.435	1.362	45.083	-413.333	4.993	5.279	1.792	-27.092	-.028
1.050	0.296	3.714	2.323	4.344	2.289	-1.305	1.439	27.028	-232.778	5.133	5.322	1.686	-26.313	-.028
1.100	0.295	4.149	2.386	3.892	[illegible]	-1.240	1.458	19.083	-153.333	5.206	5.347	1.634	-28.523	-.028
1.200	[illegible]	[illegible]	2.426	[illegible]	2.458	-1.110	1.404	13.450	-97.000	5.294	5.407	1.528	-31.057	-.028
1.350	[illegible]	[illegible]	2.542	[illegible]	2.551	-1.110	1.424	11.139	-73.889	5.313	5.407	1.528	-33.233	-.027
1.500	0.252	3.517	2.595	[illegible]	2.597	-1.110	1.490	9.983	-62.333	5.373	5.457	1.584	-37.508	-.027
1.750	0.225	2.976	2.706	3.646	2.683	-1.110	1.556	8.828	-50.778	5.432	5.507	1.639	-38.508	-.027
2.000	0.205	2.571	2.682	3.586	2.691	-1.110	1.622	7.672	-39.222	5.491	5.557	1.695	-39.508	-.026
2.500	0.182	1.984	2.798	3.440	2.800	-1.110	1.632	6.517	-27.667	5.501	5.557	1.695	-40.508	-.025
3.000	0.174	1.655	2.700	3.320	2.801	-1.110	1.626	5.361	-16.111	5.495	5.542	1.678	-40.508	-.024
4.000	0.143	1.331	2.600	3.309	2.758	-1.110	1.615	5.361	-16.111	5.485	5.532	1.667	-39.508	-.023
5.000	0.126	1.065	2.500	3.291	2.714	-1.110	1.587	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022


175MM SRC
× EXP
▲ SPIN-69
□ SPIN-73
CXO
0.30
0.20
0.10
0.00
-0.10
CNA
3.00
2.00
1.00
CMA
6.00
4.00
2.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO


175MM SRC
EXP
SPIN-69
SPIN-73
2.00
1.00
CNPA 0.00
-1.00
-2.00
20.00
0.00
CMQ -20.00
-40.00
-60.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

APPENDIX A

CURVE FIT TECHNIQUE

CURVE FIT TECHNIQUE

The method used to perform least squares fits to the experimental data using the empirical equations was a GE Time Sharing computer program code name LSQMM. This program was utilized with the GE415 computer at the Armament Systems Department. The brief description starting on the next page of this program was extracted from the following reference.

Numerical Analysis Routines #807231A
Information Service Department
General Electric Company
Bethesda, Maryland

Issued August 1968 (Revised Feb. 1969)

LSQMM

This routine determines the coefficients A(J),J=1,2,...N of the function

$$F(I) = A_1Q_{I,1} + A_2Q_{I,2} + \cdots + A_nQ_{I,n} \quad I = 1,2,\ldots,M$$

which determines the best approximation of the function Y(I) in either the weighted least squares sense or the min-max sense.

Usage

The calling sequence for this routine is:

```
CALL LSQMM(PHI,Y,A,RW,M,N,NT,NS,AM,IDIMM,IDIMN)
```

where,

- PHI is the two dimensional array, PHI(M,N), of coordinate functions which are supplied by the user. The k^{th} column of PHI contains the k^{th} coordinate function evaluated at each of the data points (i.e., - PHI(I,k), I = 1,2,..., M).
- Y is the one dimensional array, Y(M), containing the dependent variables.
- A is the one dimensional array, A(N).
  The A array contains the coefficients A(J) of the function F(I).
- RW is the name of an array containing the residuals R(I) = Y(I)-F(I), the weights W(I), and temporary storage to save the vertical weights while doing the horizontal iterations. It should contain at least 3*M locations.
- M is the number of data points.
- N is the number of coefficients, i.e., number of coordinate functions.
- NT is the maximum number of vertical iterations. For least squares fit, NT = 1.
- For least squares fit and when there is no division of the data points in min-max, NS(1) = M. Otherwise, NS is the array containing the index values of the ends of the sections when using min-max fit.
- AM is a two dimensional array, AM(N,N), used internally to contain the matrix of the system of linear equations.
- IDIMM is the first dimension of PHI, i.e., PHI(IDIMM,N).
- IDIMN is the first dimension of AM, i.e., AM(IDIMN,N).

Discussion

If the user wishes to minimize $\sum_{n=1}^{M} w_n \left[Y_n - F(X_n)\right]^2$, $w_i > 0$, modify the PHI and Y arrays as follows:

$$PHI = \begin{bmatrix} \sqrt{w_1}\,PHI(1,1) & \sqrt{w_1}\,PHI(1,2) & \cdots & \sqrt{w_1}\,PHI(1,N) \\ \sqrt{w_2}\,PHI(2,1) & \cdots & \cdots & \cdots \\ \vdots & & & \\ \sqrt{w_M}\,PHI(M,1) & \cdots & \cdots & \sqrt{w_M}\,PHI(M,N) \end{bmatrix}$$

$$Y = \begin{bmatrix} \sqrt{w_1}\,Y(1) \\ \sqrt{w_2}\,Y(2) \\ \sqrt{w_3}\,Y(3) \\ \vdots \\ \sqrt{w_M}\,Y(M) \end{bmatrix}$$

Sample Problem

Find the second degree polynomial $F = A_3 X^2 + A_2 X + A_1$, which best fits the following data in the least squares sense, where M = 9, N = 3, NT = 1.

X = -4., -3., -2., -1., 0., 1., 2., 3., 4.
Y = 2., -3., -6., -7., -6., -3., 2., 9., 18.

Solution is $F = X^2 + 2X - 6$.

Sample Solution

```
NEW
NEW FILE NAME--EXAMPLE
READY

10 COMMON PHI(9,3),X(9),A(3),RW(27)
20 COMMON AM(3,3),Y(9),YA(9),NS(1)
30 DATA M,N,NT,NS/9,3,1,9/
40 INPUT,(X(I),I=1,M)
50 INPUT,(Y(I),I=1,M)
60 CALL PHI1(M,N)
70 CALL LSQMM(PHI,Y,A,RW,M,N,NT,NS,AM,9,3)
80 DO 40 I=1,M
90 YA(I)=0.0
100 DO 30 J=1,N
110 30 YA(I)=YA(I)+A(J)*PHI(I,J)
120 40 CONTINUE
130 PRINT 100
140 100 FORMAT("      X           F(X)          Y-F(X)          A(N)
150 &     ")
170 DO 50 I=1,N
180 50 PRINT 60,X(I),YA(I),RW(I),A(I)
190 60 FORMAT(4E13.4)
200 K=N+1
210 DO 70 I=K,M
220 70 PRINT 80,X(I),YA(I),RW(I)
230 80 FORMAT(3E13.4)
240 STOP
250 END
260 SUBROUTINE PHI1(M,N)
270 COMMON PHI(9,3),X(9)
280 DO 10 I=1,M
290 10 PHI(I,1)=1.0
300 IF(N-2) 40,15,15
310 15 DO 30 I=1,M
320 DO 20 J=2,N
330 20 PHI(I,J)=X(I)**(J-1)
340 30 CONTINUE
350 40 RETURN
[illegible] END

RUN

EXAMPLE

?-4.,-3.,-2.,-1., 0.,1.,2.,3.,4.
??2.,-3.,-6.,-7.,-6.,-3.,2.,9.,18.

     X            F(X)        Y-F(X)          A(N)
 -0.[illegible]E+01  [illegible]E+01   0.          -0.6000E+01
 -0.[illegible]E+01  [illegible]     0.           0.2000E+01
 -0.2000E+01   [illegible]6000E+01   0.           0.1000E+01
 -0.1000E+01   [illegible]7000E+01   0.
  0.          -0.6000E+01    0.
  0.1000E+01  -0.3000E+01    0.
  0.2000E+01   0.2000E+01    0.
  0.3000E+01   0.9000E+01    0.
  0.400[illegible]+01   0.1800E+02    0.
```

APPENDIX B

INPUT-OUTPUT DESCRIPTION

INPUT-OUTPUT DESCRIPTION

PROGRAM NAME - SPIN-73

CODING DATE - July 1973

PURPOSE - Predict the aerodynamic coefficients of spin stabilized projectiles at Mach numbers for 0.0 to 5.0.

Inputs to the program are the projectile physical dimensions, projectile mass properties, gun bore diameter and twist, and the local air temperature.

INPUTS

Card No. 1 (See Note D)

IBM CARD COL	VARIABLE	
1 - 7	VL	Projectile length - calibers
8 - 14	VN	Ogive length - calibers
15 - 21	VB	Boattail length - calibers
22 - 28	VCG	Center of gravity - calibers for nose
29 - 35	DM	Diameter Me'Plat - calibers
36 - 42	BD[B]	Rotating band diameter - calibers
43 - 49	OR[B]	Ogive radius - calibers
50 - 56	BOOM	Boom length - calibers
57 - 80	NTITLE	Descriptor

Card No. 2 (See Note C)

1 - 7	DIA	Projectile diameter - inches
8 - 14	AX	Axial inertia - inches lb-in^2
15 - 21	TR	Transverse inertia - inches lb-in^2
22 - 28	WGT	Projectile weight - lbs.
29 - 35	TWIST	Gun twist - cal/turn
36 - 42	TEMP	Air temperature - °F
43 - 49	DGUN[B]	Gun bore diameter - inches
50 - 56	NAUTO[A]	0 Uses input dimensions 1 Automatic dimensions

A

BD set equal to 1.02 calibers
DM set equal to 0.12 calibers
OR set equal to 2 ($-VN^2$) (secant ogive)

B

If input as zero (0.0) these inputs are changed
BD set equal to 1.00 calibers
OR set equal to secant ogive
DGUN set equal to DIA

C

If aero estimates are only requirement this card should be left blank.

D

Repeat cards 1 and 2 to stack cases

OUTPUTS

Line 1 - Organization designation

Line 2 - Description of item being estimated

Line 3 - Title line - projectile dimensions

Line 4 - Projectile dimensions

Line 5 - Title line - projectile physical properties, gun properties air temperature and density

Line 6 - Projectile physical properties, gun properties, air temperature and density

Line 7 - 'Aerodynamic Coefficients'

Line 8 - Title line - Mach No., etc.

Line 9 -

Cxo	- Zero yaw axial force coefficient
CX2	- Yaw axial force coefficient per $\sin^2 \bar{\alpha}$
CNA	- Normal force coefficient derivative per $\sin \bar{\alpha}$
CMA	- Pitching moment coefficient derivative per $\sin \bar{\alpha}$
CPN	- Normal force center of pressure - calibers for nose
CYP	- Magnus force coefficient derivative per $\sin \bar{\alpha}$
CNPA	- Zero yaw Magnus moment coefficient derivative per $\sin \bar{\alpha}$
CNPA3	- Cubic Magnus moment coefficient derivative per $\sin^3 \bar{\alpha}$
CNPA5	- Quintic Magnus moment coefficient derivative per $\sin^5 \bar{\alpha}$
CPF1	- Center of pressure of Magnus force at 1° yaw or less calibers from nose
CPF5	- Center of pressure of Magnus force at 5° yaw, calibers from nose
CNPA-5	- 5° - Secant slope of Magnus moment coefficient derivative (at 5° yaw) per $\sin \bar{\alpha}$
Cmq	- Damping moment coefficient
Clp	- Spin deceleration coefficient

Line 10 - 'Stability Analysis'

GYRO	Gyroscopic stability factor
SBAR	Dynamic stability factor at 1° yaw
RECIP	Dynamic reciprocal factor at 1° yaw
SBAR5	Dynamic stability factor at 5° yaw
RECIP5	Dynamic reciprocal factor at 5° yaw
SPIN	Spin rate, radians/second
W1	Nutation frequency, radians/second
W2	Precession frequency, radians/second
L1	Nutation damping factor per foot @ 1° yaw
L2	Precession damping factor per foot @ 1° yaw
L1-5	Nutation damping factor per foot @5° yaw
L2-5	Precession damping factor per foot @ 5° yaw
DELT	Integration time step, seconds (20 per nutation)
DISP	Dispersion factor per 5° first max yaw, mils

APPENDIX C

PROGRAM LISTING

SPIN-73

```
      DIMENSION [illegible] (17),SF5(17),W1(17),W5(17),
     1 XA1(17),XA2(17),XC1(17),XF1(17),XA2(17),XB2(17),XC2(17),XD2(17),
     2 XA3(17),XB3(17),XC3(17),XD3(17),XA4(17),XB4(17),XC4(17),XD4(17),
     3 XA5(17),XB5(17),XC5(17),           ,XA6(17)          ,XC6(17),
     4 XA7(17),XC7(17),XA8(17),XC8(17),XA9(17),XC9(17),XA10(17),XC10(17
     4),XA11(17),XC11(17),XA12(17),XC12(17),XA13(17),XC13(17),XA14(17),
     5 XC14(17),XC17(17),
     6                     CYPS(17),CPC1(17),CPC2(17),CPC5(17),
     7          SLOP(17),SCLP(17),STAR(17),SIGMA(17),P(17),W1(17),W2(17),
     8          AL1(17),AL2(17),BL1(17),BL2(17),DELT(17),NTITLE(6)
      DIMENSION XF1(17),XF2(17),XF3(17),XF4(17),XF5(17),XF6(17),XF7(17)
      DIMENSION XE1(17),XE2(17),XE3(17),XE4(17)
      DIMENSION XFM(17),XB6(17),XB7(17),XB8(17),XB9(17),XB10(17),
     1 XC1[illegible](17),XC15(17
      DIMENSION XA1[illegible](17),XF5(17),XF9(17),XG1(17)
      DIMENSION [illegible]


      DATA [illegible] / [illegible].01,[illegible],0.6,0.8,0.9,0.95,1.0,1.05,1.1,1.2,1.35,1.5,1.75,
     1 2.0,2.5,3.,[illegible]4.0,5.  /
      DATA XA1/.[illegible],.2[illegible],.2034,.2195,.2732,.3675,.4129,.4084,.3938,
     & .3737,.3560,.3285,.3054,.2677,.2410,.203,.181/
      DATA XA2/.0357,.0[illegible],.0057,.0029,-.0141,-.0324,-.0487,-.0694,
     & -.0764,-.0740,-.0723,-.0695,-.0633,-.0559,-.0463,-.0463,-.0463/
      DATA XA3/.012[illegible],.0[illegible]1,.0121,.0181,.0052,.0152,.0441,.0426,.0476,
     & .0419,.0384,.0325,.0265,.0123,.0044,.0044,.0044/
      DATA XA4/0.0,0.0,0.0,0.0,0.0,0.0,0.0,.0160,.0102,.0033,
     & -.0082,-.0145,-.0251,-.0381,-.053,-.061,-.061,-.061/
      DATA XA5/-.0138,-.0138,-.0138,-.0367,-.0389,-.0399,-.0396,-.0349,
     & -.0229,-.0192,-.0165,-.0118,-.0092,-.0106,-.0157,-.0157,-.0157/
      DATA XA6/.0128,.0128,.0128,.0382,.0410,.0379,.0293,.0262,.0182,
     & .0157,.0132,.0099,.0059,.0043,.0043,.0043,.0043/
      DATA XA7/-.2295,-.2295,-.2295,-.2058,-.1944,-.1475,-.0892,-.0879,
     & -.0828,-.0788,-.0749,-.0683,-.0652,-.0484,-.0330,-.0330,-.0330/
      DATA XA8/-.0071,-.0071,-.0071,-.0212,-.0197,-.042,-.0664,-.0586,
     &-.0366,-.0240,-.0162,-.0034,.0103,.0261,.0370,.037,.037/
      DATA XA9/0.0,0.0,0.0,.0114,-.0016,.1216,.2278,.2253,.2023,.198,
     & .1884,.1725,.1471,.1024,.0447,.0447,.0447/
      DATA XA10/.025,.025,.025,.04,.07,.02,.11,.10,.0983,.0967,.095,.09,
     & .085,.070,.060,.050,.040/
      DATA XA11/ .4      , .4      , .4      , .55     , .7      , .725    , .75     ,
     C          .8      , .9      , .85     , .8      , .745    , .69     , .65     ,
     C          .55     , .55     , .55     /
      DATA XA12/ .07     , .07     , .07     , .11     , .13     , .15     , .17     ,
     C          .21     , .26     , .37     , .48     , .73     , .98     ,1.45     ,
     C         1.8      ,1.8      ,1.8      /
      DATA XA13/0.0,0.0,0.0,0.004,0.006,0.031,0.050,0.050,0.044,0.030,
     1 0.025,0.021,0.018,0.016,0.015,0.013,0.012/
      DATA XA14/0.0,0.0,0.0,0.000,0.000,0.040,0.065,0.060,0.057,0.053,
     1 0.050,0.047,0.043,0.040,0.035,0.027,0.022/
      DATA XA15/0.0,0.0,0.0,0.035,0.040,0.053,0.055,0.046,0.030,0.023,
     1 0.020,0.01[illegible],0.0[illegible]0,0.005,0.004,0.003,0.002/
      DATA XB1/2.2,2.2,2.2,2.22,2.25,2.27,2.295,2.32,2.34,2.40,2.49,2.60,
     1 2.70,2.80,2.90,2.85,2.75,2.65/
```

```
23        DATA X[illegible] / [illegible],[illegible],1.0767,0.0450,0.0261,[illegible],-.0593,-.0575,
         1 -.0617,-.0680,-.0744,-.0596,-.0647,-.0744,-.0841,-.0841,-.0841 /
25        DATA XH3 /-.0255,-.0255,-.0255,-.0280,-.0292,-.0305,-.0126,-.0119,
         1 -.0[illegible],-.0084,-.0061,0.0006,0.0059,0.0136,0.0226,0.0226,0.0226 /
26        DATA XH4 /-.0856,-.0898,-.0898,-.0986,-.1029,-.1073,-.1824,-.1698,
         1 -.1446,-.1368,-.0696,-.0435,-.0091,0.0599,0.1288,0.1288,0.1288 /
27        DATA XH5 /-.0606,-.0606,-.0606,-.0047,0.0233,0.0512,0.1492,0.1433,
         1 0.13[illegible],0.1149,0.0965,0.1145,0.0966,0.0697,0.0249,0.0249,0.0249 /
28        DATA X[illegible] /0.0185,0.0185,0.0185,0.0185,0.0185,0.0185,0.0119,0.0119,
         1 0.0119,0.0119,0.0119,0.0110,0.0110,0.0110,0.0110,0.0110,0.0110 /
29        DATA X[illegible] /-1.022,-1.022,-1.022,-.9861,-1.050,-.7469,-.4567,-.3710,
         1 -.3[illegible],-.2256,-.1[illegible],-.1340,-.1012,0.0029,0.0029,0.0029,0.0029 /
30        DATA XH8 /-.1801,-.1801,-.1801,-.1801,-.2870,-.2870,-.3125,-.3125,
         1 -.2857,-.2857,-.2854,-.2854,-.1940,-.1280,-.1280,-.1280,-.1280 /
31        DATA XH9 /-.0450,-.0450,-.0450,-.0450,-.2747,-.2747,-.2083,-.2083,
         1 -.1646,-.1646,-.1110,-.1110,0.0081,0.0252,0.0252,0.0252,0.0252 /
32        DATA XC1/1.71,1.70,1.66,1.63,1.60,1.58,1.56,1.55,1.57,1.63,1.70,
         1 1.79,1.88,1.90,2.03,2.00,1.97/
33        DATA XC2 /0.6995,0.6995,0.6995,0.7224,0.7301,0.7314,[illegible],0.5614,
         1 0.5614,0.5595,0.5553,0.5324,0.5195,0.4993,0.4867,0.4867,0.4867 /
34        DATA XC3 /-.4425,-.4425,-.4425,-.3199,-.2661,-.2174,0.1353,0.1304,
         1 0.1214,0.1094,0.0992,0.0996,0.0844,0.0889,0.1376,0.1376,0.1376 /
35        DATA XC4 /-.2241,-.2241,-.2241,-.2241,-.2241,-.2241,0.1044,0.1044,
         1 0.1044,0.1044,0.1044,0.1188,0.1188,0.1188,0.1188,0.1188,0.1188 /
36        DATA XC5 /0.0136,0.0136,0.0136,0.0172,0.0190,0.0267,0.0542,0.0514,
         1 0.0466,0.0377,0.0295,0.0216,0.0170,0.0078,-.0014,-.0014,-.0014 /
37        DATA XC6 /0.0449,0.0447,0.0449,0.0413,0.0395,0.0377,0.0001,-.0001,
         1 -.0006,-.0014,-.0021,-.0065,-.0093,-.0150,-.0207,-.0207,-.0207 /
38        DATA XC7 /-.0016,-.0016,-.0016,-.0016,-.0016,-.0016,0.0033,0.0033,
         1 0.0033,0.0033,0.0033,0.0036,0.0036,0.0036,0.0036,0.0036,0.0036 /
39        DATA XC8 /-.5470,-.5470,-.5470,-.5793,-.5955,-.6117,-.6854,-.6770,
         1 -.5601,-.6348,-.6096,-.5742,-.5429,-.4804,-.4178,-.4176,-.4178 /
40        DATA XC9 /-.1383,-.1383,-.1383,0.0278,0.1109,0.1939,0.4924,0.4636,
         1 0.4061,0.3199,0.2336,0.1217,0.0431,-.1142,-.2714,-.2714,-.2714 /
41        DATA XC10/-.7422,-.7422,-.7422,-.7422,-.7422,-.7422,-.6280,-.6280,
         1 -.6280,-.6280,-.6280,-.6031,-.6031,-.6031,-.6031,-.6031,-.6031 /
42        DATA XC11/-.4712,-.4712,-.4712,-.4712,-.4712,-.4712,-.6396,-.6257,
         1 -.5977,-.5557,-.5138,-.4768,-.4303,-.3332,-.2361,-.2361,-.2361 /
43        DATA XC12/-3.650,-3.670,-3.897,-4.174,-4.203,-2.936,-1.686,-1.314,
         1 -1.162,-.3[illegible]4,-.4[illegible]3,-.3949,-.2274,0.1794,0.1794,0.1794,0.1794 /
44        DATA XC13/-.9349,-.9439,-.9349,-1.748,-1.748,-1.748,-1.933,-1.933,
         1 -1.474,-1.474,-1.427,-1.427,-.9122,-.6300,-.6300,-.6300,-.6300 /
45        DATA XC14/0.3306,0.3306,0.3306,0.3306,-.7872,-.7872,-.9731,-.9731,
         1 -.6906,-.6906,-.5391,-.5391,0.0271,0.2332,0.2332,0.2332,0.2332 /
46        DATA XC15/0.0    ,0.0   ,0.0   ,0.0   ,0.6954,0.7100,1.0097,1.0043,
47        DATA XC16/0.0    ,0.0   ,0.0   ,0.0   ,5.0334,5.9629,11.766,11.457,
47        DATA XC16/0.0    ,0.0   ,0.0   ,0.0   ,5.0334,5.9629,11.768,11.457,
         1 9.1474,8.4991,7.6984,6.6724,6.1030,6.1493,6.1493,6.1493,6.1493 /
48        DATA XC17/0.35,0.35,0.35,0.35,0.35,0.37,0.44,0.44,0.44,0.42,
         1 0.35,0.30,0.30,0.28,0.28,0.28,0.28/
49        DATA XD1 /4.5    ,4.5    ,5.     ,5.5    ,6.     ,6.5    ,7.     ,
         C          7.5    ,8.     ,7.5    ,7.     ,6.5    ,6.     ,5.5    ,
         C          5.     ,4.5    ,4.     /
50        DATA XD2 / .25   , .25   , .25   , .25   , .25   , .3    , .35   ,
```

```
          C        .4     , .5    , .5    , .5    , .5    , .5    , .5    ,
          C        .45    , .4    , .35   /
   51      DATA XD3 / .3  , .5    , .5    , .5    , .6    , .7    , .8    ,
          C        .9     , 1.    , 1.    , 1.    , 1.    , 1.    , .8    ,
          C        .7     , .6    , .5    /
   52      DATA XF4 /-1.  , -1.   , -1.   , -.9   , -.8   , -.7   , -.6   ,
          C        -.5    , -.4   , -.3   , -.2   , -.1   , 0.    , 0.    ,
          C        0.     , 0.    , 0.    /
   53      DATA XF1 /-.16 , -.16  , -.16  , -.18  , -.23  , -.21  , -.19  ,
          C        -.18   , -.16  , -.16  , -.16  , -.16  , -.16  , -.16  ,
          C        -.16   , -.16  , -.16  /
   54      DATA XF2 /1.6  , 1.8   , 2.    , 2.4   , 2.7   , 2.8   , 2.9   ,
          C        2.95   , 2.98  , 3.00  , 3.01  , 3.02  , 3.03  , 3.04  ,
          C        3.05   , 3.05  , 3.05  /
   55      DATA XF3 /2.5  , 2.5   , 2.6   , 2.75  , 2.9   , 3.    , 3.06  ,
          C        3.07   , 3.08  , 3.08  , 3.08  , 3.09  , 3.09  , 3.09  ,
          C        3.09   , 3.09  , 3.09  /
   56      DATA XF4 /2.9  , 2.9   , 3.    , 3.05  , 3.1   , 3.1   , 3.1   ,
          C        3.1    , 3.1   , 3.1   , 3.1   , 3.1   , 3.1   , 3.1   ,
          C        3.1    , 3.1   , 3.1   /
          1 0.3,0.3,0.27,0.25,0.20/
          1 0.3,0.3,0.27,0.25,0.20/
   58      DATA XF1 /1.72 , 1.72  , 1.72  , 2.31  , 2.88  , 3.79  , 3.84  ,
          C        4.24   , 4.64  , 4.93  , 5.21  , 5.21  , 5.21  , 5.21  ,
          C        5.21   , 5.21  , 5.21  /
   59      DATA XF2 /3.18 , 3.18  , 3.18  , 3.18  , 3.18  , 3.18  , 3.18  ,
          C        3.29   , 3.4   , 3.4   , 3.4   , 3.4   , 3.4   , 3.4   ,
          C        3.40   , 3.40  , 3.40  /
   60      DATA XF3 /1.06 , 1.06  , 1.06  , 1.05  , 1.04  , 1.03  , 1.02  ,
          C        1.01   , 1.    , 1.    , 1.    , 1.    , 1.    , 1.    ,
          C        1.     , 1.    , 1.    /
   61      DATA XF4 /-3.3 , -3.3  , -3.3  , -3.2  , -3.18 , -3.16 , -3.13 ,
          C        -3.00  , -3.00 , -2.50 , -1.59 , -1.59 , -1.59 , -1.59 ,
          C        -1.59  , -1.59 , -1.59 /
   62      DATA XF5 /-1.3 , -1.3  , -1.3  , -1.3  , -1.3  , -1.3  , -1.3  ,
          C        -1.26  , -1.26 , -1.26 , -1.26 , -1.26 , -1.26 , -1.26 ,
          C        -1.26  , -1.26 , -1.26 /
   63      DATA XF6 /0.   , 0.    , 0.    , 0.    , 0.    , 0.    , 0.    ,
          C        0.     , 0.    , 0.    , 0.    , 0.    , 0.    , 0.    ,
          C        0.     , 0.    , 0.    /
   64      DATA XF7 /-.7  , -.7   , -.7   , -.7   , -.7   , -.7   , -.7   ,
          C        -.73   , -.73  , -.73  /
          C        -.73   , -.73  , -.73  /
   65      DATA XF8 /1.09 , 1.09  , 1.09  , .8    , .6    , .3    , -.002 ,
          C        -.23   , -.47  , -1.15 , -1.83 , -1.83 , -1.83 , -1.83 ,
          C        -1.83  , -1.83 , -1.83 /
   66      DATA XF9 /0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1.0,2.0,4.0,
          1 6.0,8.0,8.0,6.0.3.0/
   67      DATA XG1  / -.0364,-.0364,-.0346,-.0292,-.0254,-.0240,-.0238,
          1 -.0236,-.0234,-.0232,-.0230,-.0225,-.0220,-.0210,-.0200,-.0195,   SPIN1430
          2 -.0190 /                                                          SPIN1440
        C                                                                     SPIN1450
   68    1001 FORMAT(8F7.0,6A4)
   69    1002 FORMAT(7F7.0,20X,1nI1)
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1999 FORMAT(1H1)
2000 FORMAT(  49X,23H GE BURLINGTON VERMONT  /50X,6A4//)
2001 FORMAT(13X,5HTOTAL,10X,5HNOSE ,8X,9HBOAT TAIL,9X,3HCG ,10X,7HMEPLA
    *T ,9X,5HBAND ,11X,5HNOSE ,11X,5HBOOM /4X,3(8X,7HLENGTH ),7X,9H(FM
    *NOSE),2(6X,9HDIAMETER ),8X,6HRADIUS,10X,6HLENGTH )
2002 FORMAT(8X,8(F10.3,5X))
2003 FORMAT(//  3X,9HDIAMETER ,9X,3HIX ,12X,3HIY ,10X,7HWEIGHT ,7X,9HGU
    *N TWIST,4X,13HACTUAL TWIST ,4X,9HGUN-BORE ,5X,11HTEMPERATURE,4X,11
    *HAIR DENSITY/ 4X,7HINCHES ,1X,2(6X,9HLB-IN-SQ ),9X,3HLBS,3X,2(6X,9
    *HCAL/TURN ),7X,7HINCHES ,9X,5HDEG-F,7X,11HSLUGS/FT**3 )
2004 FORMAT(1X,8(F10.3,5X),F10.5)
2005 FORMAT(   //48X,26H AERODYNAMIC COEFFICIENTS //5X,5HMACH ,5X,3HCX
    * ,6X,3HCX2,6X,3HCNA,6X,3HCMA,6X,3HCPN,5X,5HCYPA ,4X,5HCNPA ,4X,5HC
    *LP)
    *LP)
2006 FORMAT(1X,15F9.3)
2007 FORMAT(   //52X,20H STABILITY ANALYSIS //5X,5HMACH ,4X,5HGYRO ,4X,
    *5HSBAR ,4X,5HRECIP,3X,7HSBAR*5 ,2X,7HRECIP*5,3X,5HSPIN ,5X,3HW1 ,6
    *X,3HW2 ,6X,3HL1 ,6X,3HL2 ,5X,5HL1*5 ,4X,5HL2*5 ,4X,4HDELT,5X,
    & 4HDISP)
2008 FORMAT(1X,6F9.3,F9.1,2F9.2,4F9.6,F9.4,F9.3)
2010 FORMAT(1X,2F9.3        ,5X,23H GYROSCOPIC INSTABILITY )
3999 FORMAT(10F7.3)
      IW=6
      IR=50
    1 READ(IR,1001) VL,VN,VB,VCG,DM,FD,OR,BOOM,(NTITLE(I),I=1,6)
      CALL EOFTST(IR,I)
      IF(I.EQ.2) STOP
      READ(IR,1002)DIA,AX,TR,WGT,TWIST,TEMP,DGUN,NAUTO,NAERO,NSAUL,NNOL,
     *NOLICK,NGRAPH
      IF(NAUTO-1)3,2,2
    2 BD=1.02
      DM=.12
      OR=VA*VN*2.
    3 RHC=.002376+(-4.784*(TEMP-59.)+.01092*(TEMP-59.)**2)*.000001
      ASSO =49.04*SQRT(459.6+TEMP)
      IF(DGUN)4,4,5
    4 IF(DIA) 155,155,45
   45 DGUN=DIA
    5 TT=(1./TWIST*DIA/DGUN)**2
      T=1.0/TWIST
  155 CONTINUE
      IF(BD)6,6,7
    6 BD=1.
    7 IF(OR)8,8,9
    8 OR=VA*VN*2.
    9 CONTINUE
      WRITE(IW,1999)
      WRITE(IW,2000)(NTITLE(I),I=1,6)
      WRITE(IW,2001)
      WRITE(IW,2002) VL,VN,VB,VCG,DM,BD,OR,BOOM
      WRITE(IW,2003)
      WRITE(IW,2004) DIA,AX,TR,WGT,TWIST,TWIST*DGUN/DIA,DGUN,TEMP,RHO
C     SETUP OF CONSTANTS                                                SPIN1680
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C     SETUP OF CONSTANTS                                        SPIN1680
      ZRO=0.0                                                   SPIN171
      ZPTV=0.25                                                 SPIN1720
      ZPV=0.5                                                   SPIN1730
      ONE=1.0                                                   SPIN1740
      TWO=2.0                                                   SPIN1750
      POR=4.0                                                   SPIN1790
      POR=4.0                                                   SPIN1790
      VIV=5.0                                                   SPIN1800
      SENG=5.51                                                 SPIN1810
      TLV=12.0                                                  SPIN1820
      GRAVVY=32.174                                             SPIN1830
      DD=DIA*DIA                                                SPIN1850
      FD=DIA**VIV                                               SPIN1860
      XX=AY*AX                                                  SPIN1870
      D=DIA/TLV                                                 SPIN1880
      AR=D*D*0.7854                                             SPIN1890
      AXL=AX/(TLV*TLV)                                          SPIN1900
      TRL=TR/(TLV*TLV)                                          SPIN1910
      A=AXL/GRAVVY                                              SPIN1920
      B=TRL/GRAVVY                                              SPIN1930
      VVLL=VL*VL                                                SPIN1940
      TK=(WGT*DD)/AX                                            SPIN1970
      BK=(WGT*DD)/TR                                            SPIN1980
      FACT=RHO*GRAVVY*AR/(POR*WGT)                              SPIN1990
      DKH=((VVLL/VIV)-VL)*5.73                                  SPIN2080
      CVL=VL
      CXCL=VL-VN-VB-1.5
      CVN=VN-2.5
      CVB=VB
      CBD=BD-1.02
      CRDD=RD-1.
      CDM=(DM-.12)**2
      CRAT=VN*VN/OR-.4
      CCG=VCG-3.0
      CLL=VL-5.0
      DO 500 J=1,17                                             SPIN2090
C      AXIAL FORCE
      VBX=VB-0.20
      IF(VBX.LT.0.0) VBX=0.0
      VNX=VN
      CXCLL=CXCL
      DXBT=0.0
      DXN=0.0
      DXCL=0.0
  301 VBX=0.45
  301 VBX=0.45
      IF(VB-1.0) 307,307,308
  307 DXBT=(VB-0.65)*XA10(J)
      GO TO 302
  308 DXBT=XA10(J)*0.35+(VB-1.0)*XA10(J)*0.3333
  302 IF(VN.LE.3.0) GO TO 304
      VNX=3.0
      IF(VN.GT.3.48) GO TO 309
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      DXN=(VN-3.0)*XA13(J)
      GO TO 304
  309 IF(VN.GT.3.97) GO TO 310
      DXN=0.48*XA13(J)+(VN-3.48)*XA14(J)
      GO TO 304
  310 DXN=0.48*XA13(J)+0.49*XA14(J)+(VN-3.97)*XA15(J)
  304 IF(CXCL-1.5) 306,306,305
      DXCL=(CXCL -1.5)*0.010
      DXCL=(CXCL -1.5)*0.010
  306 CONTINUE
      CX0=XA1(J)+XA2(J)*(VNX-2.5)+XA3(J)*(VNX-2.5)**2*XA4(J)*(VNX-2.5)**
     13+XA5(J)*CXCLL+XA6(J)*CXCLL**2+XA7(J)*VBX
     2 +XA8(J)*CRAT+XA9(J)*CRAT**2
     3 + XA11(J)*CHD*XA12(J)*CDM-(BOFM/1.36)**2*0.01
     4 -DXRT-DXN+DXCL
C     COMPUTATION OF CONSTANTS FOR CNA AND CHA
      VRX=VR
      DNX=0.0
      IF(VN-3.0) 11,11,10
   10 VNX=3.0
      DNX=VN-3.0
      GO TO 12
   11 CONTINUE
      VNX=VN
   12 IF(VR-1.0) 14,14,13
   13 VBX=1.0
      VBNP=VR**0.5
      VBRP=VR**0.5
      GO TO 25
   14 CONTINUE
      IF(J.GE.5) GO TO 20
      VBNP=VR
      VBRP=VR**0.8
      GO TO 25
   20 CONTINUE
      VBNP=VR**1.5
      VBRP=VR
   25 CONTINUE
      CVNN=VNX-2.47
      CDMM=DM-0.17
      CBFD=BD-1.04
      CBFD=BD-1.04
      CCRT=VN*VN/OR-0.48
      VRTT=CVL/4.7
      CNAB=XB1(J)+XB2(J)*CVNN+XB3(J)*CXLL+XB4(J)*CCRT*XB5(J)*CVNN*CVNN
     1 *XB6(J)*CXLL*CXLL
      CNBT=VRNP*XB7(J)+VRX*CVNN*XB8(J)+VBX*CXLL*XB9(J)
      IF(CART.GT.0.0) CNBT=0.0
      CNAT=CNAB+CNBT
      AMCMSQ=CNAB+(XC1(J)+XC2(J)*CVNN+XC3(J)*CVNN*CVNN+XC4(J)*CVNN
     1*CVNN*CVNN*XC5(J)*CXLL+XC6(J)*CXLL*CXLL+XC7(J)*CXLL*CXLL*CXLL
     2+XC8(J)*CCRT+XC9(J)*CCRT*CCRT+XC10(J)*CDMM
     3 +XC11(J)*CCRT*CVNN+DNX*XC17(J))
      AMCMRT=VRTT*(VRMP*XC12(J)+VBX*CVNN*XC13(J)+VBX*CXLL*XC14(J)
```

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```
     4 *VHY*CHT*XC15(J)+VRX*CCRT*CVKN*XC16(J))
      IF(AMOMBT.GT.0.0) CNAT=CNAR
      IF(AMOMBT.GT.0.0) AMOMBT=0.0
      CPN=(AMOMSQ+AMOMHT)/CNAT
      CMA=(VCG-CPN)*CNAT
      CX2=XD1(J)+XD2(J)*CXCL+XD3(J)*CRAT+XD4(J)*CVR*CNAT
C     COMPUTE CYPA                                                      SPIN3010
      CYP=XE1(J)*CV
      CYPA=CYP-0.1*CVM
C     COMPUTE CPF AND CNPA AT A=1.0                                     SPIN3030
      DCPF=0.0
      IF(VL.LE.6.0) GO TO 28
      DCPF=(VL-6.0)*XE5(J)
   28 CONTINUE
      CNPAN=-CYP*(XE2(J)+0.55*CXCL+0.8*CVN)
     C +1.0*CVL/4.7*CVB
      CPF=-CNPAN/CYPA
      CPF=CPF+DCPF
      CNPA =(VCG-CPF )*CYPA
C     COMPUTE CPF AND CNPA AT A=2.0                                     SPIN3060
      CNPAN=-CYP*(XE3(J)+0.55*CXCL+0.8*CVN)
     C +1.0*CVL/4.7*CVB
      CPFA2=-CNPAN/CYPA
      CPFA2=CPFA2+DCPF
      CNPAA2=(VCG-CPFA2)*CYPA
C     COMPUTE CPF AND CNPA AT A=5.0                                     SPIN3090
      CNPAN=-CYP*(XE4(J)+0.55*CXCL+0.8*CVN)
     C +1.0*CVL/4.7*CVB
      CPFA5=-CNPAN/CYPA
      CPFA5=CPFA5+DCPF
      CNPAA5=(VCG-CPFA5)*CYPA
C     COMPUTE CMG                                                       SPIN3120
      DCMQ=0.0
      IF(VL.LE.6.0) GO TO 30
      DCMQ=(VL-6.0)*XF9(J)
   30 CONTINUE
      CK =XF1(J)+XF2(J)*CLL+XF3(J)*CLL**2+XF4(J)*CCG+XF5(J)*CCG*CLL+XF6(
     *J)*CCG*CLL*CLL+XF7(J)*CCG*CVB+XF8(J)*CVB
      CMQ=-5.093*CKM
      CMQ=CMQ-DCMQ
C     COMPUTE CLP                                                       SPIN3180
      CLP= XG1(J)*VL/SPNG
C                                                                       SPIN3200
C                                                                       SPIN3210
C     STABILITY CALCULATIONS                                            SPIN3220
      IF(DIA)555,555,554                                                SPIN3230
  554 STAB(J)=1352.4*XX*TT/(R*RHO*FC*CMA)                               SPIN3240
      ROT1=CNAT-CX3-(BK*ZPV*CMQ)+(TK*ZPV*CLP)
      ROT1=CNAT-CX0-(HK*ZPV*CMQ)+(TK*ZPV*CLP)
      SBAR1=TOP1/ROT1                                                   SPIN3270
      RECP1=ONE/(SBAR1*(TWO-SBAR1))                                     SPIN3280
      TOP5=TWO*(CNAT-CX0+TK*ZPV*CNPAA5)
      SBAR5=TOP5/ROT1                                                   SPIN3300
      RECP5=ONE/(SBAR5*(TWO-SBAR5))                                     SPIN3310
```

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   54 IF(STAR(J)-1.001) 56,55,55                                           SPIN3320
   55 SS=ONE-(ONE/STAR(J))                                                 SPIN3330
      SIGMA(J)=SS**ZEV                                                     SPIN3340
      VEL=CMACH(J)*ASSD
      P(J)=76.283*VEL/D*DIA/DGUN
      R1(J)=(P(J)*AX/(TWO*TH))*(ONE+SIGMA(J))                              SPIN3380
      R2(J)=(P(J)*AX/(TWO*TH))*(ONE-SIGMA(J))                              SPIN3390
      DISP(J)=((CNAT-CXO)*TH*(R1(J)-R2(J))*3.635)/(CMA*RGT*DIA*VEL)
      TAU=ONE/SIGMA(J)                                                     SPIN3400
      A1=FACT*((-CNAT)*(ONE-TAU)+(RK/TWO)*(ONE+TAU)*CMO+TK*TAU*CNPA)
      A2=FACT*((-CNAT)*(ONE+TAU)+(RK/TWO)*(ONE-TAU)*CMO-TK*TAU*CNPA)
      B1=FACT*((-CNAT)*(ONE-TAU)+(RK/TWO)*(ONE+TAU)*CMO+TK*TAU*CNPAA5)
      B2=FACT*((-CNAT)*(ONE+TAU)+(RK/TWO)*(ONE-TAU)*CMO-TK*TAU*CNPAA5)
      AL1(J)=A1                                                            SPIN3450
      AL2(J)=A2                                                            SPIN3460
      BL1(J)=B1                                                            SPIN3470
      BL2(J)=B2                                                            SPIN3480
      DELT(J)=6.28/(W1(J)*20.0)
      GO TO 56                                                             SPIN3500
  555 STAR(J)=ZRO                                                          SPIN3510
      SBAR1=ZRO                                                            SPIN3520
      RECP1=ZRO                                                            SPIN3530
      RECP5=ZRO                                                            SPIN3540
      SBAR5=ZRO                                                            SPIN3550
   56 CONTINUE
      SD1(J)=SBAR1
      R1(J)=RECP1
      SD5(J)=SBAR5
      R5(J)=RECP5
      XMAG1=CNPAA5-CNPA
      XMAG2=CNPAA5-CNPA+0.3
      CNPA5=(XMAG2-9.0*XMAG1)/0.0072
      CNPA3=(XMAG1-CNPA5*.0001)/0.01
  556 WRITE(IW,2006)CMACH(J),CXO,CX2,CNAT,CMA,CPN,CYPA,CNPA,CNPA3,CNPA5,
     1 CPF,CPFA5,CNPAA5,CMO,CLP
  500 CONTINUE                                                             SPIN3690
      IF(DIA)1,1,558                                                       SPIN3700
  558 WRITE(6,2007)
      DO 501 J=1,17                                                        SPIN3740
      IF(STAR(J)-1.001) 57,58,58                                           SPIN3750
   57 WRITE(6,2010) CMACH(J),STAR(J)
      GO TO 59                                                             SPIN3770
   58 WRITE(IW,2008) CMACH(J),STAB(J),SD1(J),R1(J),SD5(J),R5(J),P(J),
     1 W1(J),W2(J),AL1(J),AL2(J),BL1(J),BL2(J),DELT(J),DISP(J)
   59 CONTINUE                                                             SPIN3800
  501 CONTINUE                                                             SPIN3810
      GO TO 1                                                              SPIN3820
C                                                                          SPIN3830
C                                                                          SPIN3840
      END                                                                  SPIN4130
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13 ABSTRACT

The SPINNER computer program has been updated to compute aerodynamic coefficients for a wide variety of spin stabilized projectile shapes. Improvements over the original program are substantial as ogive radius, meplat diameter and rotating band diameter are accounted for instead of assuming mean values. Test cases are shown compar[illegible] the 1969 SPINNER, the 1973 SPINNER and experimental data. Input instructions and sample program outputs are given along with the 1973 program listing.

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